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Universal adhesive systems in dentistry: A narrative review

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ABSTRACT

BACKGROUND: Various innovative solutions are being adopted in dentistry to reduce the risk of treatment-related complications. Latest-generation adhesive systems are important for preventing microleakages and improving the adhesion of filling materials to tooth structures, resulting in effective use of esthetic restoration materials and long-lasting restorations.

AIM: To assess the current use of universal adhesive systems.

MATERIALS AND METHODS: The literature search was performed using PubMed, eLIBRARY.RU, and Google Scholar. The following search terms were used: “universal adhesive systems”, “universal adhesives”, “dentin bonding agents”, “dental debonding” and “dental etching”. The search covered studies published during the last 10 years.

RESULTS: The initial search yielded 1.284 publications. After screening for compliance with search terms, 106 studies were selected. Following a full-text analysis, 31 (100%) publications were included in the review. Of these, 14 (45%) studies addressed adhesive composition (examined component: hydrophilic monomers, nanofillers, hydrophobic monomers, solvents, etchants); 8 (26%) studies addressed adhesive strength of adhesives (air-powder abrasive surface treatment, smear layer characteristics, surface moisture, bonding agent type, testing conditions); and 9 (29%) addressed application method (etching type).

CONCLUSION: Universal adhesive systems have a wide range of clinical applications (various methods of surface preparation) and clinical scenarios, expanding their potential use. The findings of the literature review describe various applications of universal adhesive systems with various surface preparation techniques, with mixed results. Conflicting literature data highlight the importance of investigating the long-term use of universal adhesives with various clinical settings and protocols.

Keywords: universal adhesive systems; universal adhesives; dentin bonding agents; dental debonding; dental etching.

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Применение универсальных адгезивных систем в стоматологии: нарративный обзор

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АННОТАЦИЯ

Обоснование. Использование новейших разработок в стоматологической практике направлено на минимизацию осложнений, возникающих в процессе лечения. Применение адгезивных систем последнего поколения имеет важное значение для решения проблемы микроподтекания, повышения прочности связи между пломбировочным материалом и структурами зуба и, следовательно, успешного применения эстетических реставрационных материалов в перспективе долговечности реставрации.

Цель работы — изучить современное состояние применения универсальных адгезивных систем.

Материалы и методы. Поиск литературных источников проводили с помощью следующих поисковых баз: PubMed, eLIBRARY.RU, Google Scholar. Подбор источников проводили, используя следующие ключевые запросы: «универсальные адгезивные системы», «универсальные адгезивы», «бонды для дентина», «разрушение связи с тканями зуба», «дентальное протравливание», «universal adhesive systems», «universal adhesives», «dentin bonding agents», «dental debonding», «dental etching». Глубина поиска составила 10 лет.

Результаты. По итогам первоначального поиска было найдено 1284 публикации. После проверки статей на соответствие условиям поиска, было отобрано 106 работ. Проведённый полнотекстовый анализ стал основанием для включения в данный обзор 31 (100%) источника. По вопросам состава адгезива (изучаемый компонент: гидрофильные мономеры, нанонаполнители, гидрофобные мономеры, растворители, травящий агент) изучено 14 (45%) статей; по адгезионной прочности адгезива (воздушно-абразивная обработка поверхности, характеристики смазанного слоя, влажность поверхности, тип бонда, условия испытаний) — 8 (26%) работ; по принципу применения (характеру протравливания) — 9 (29%) публикаций.

Заключение. Выбор клинических вариантов применения универсальных адгезивных систем (различных стратегий подготовки поверхности) и клинических ситуаций во многом расширяет возможности использования универсальных адгезивов. Полученные в ходе анализа источников данные описывают разнообразие способов применения универсальных адгезивных систем в разных техниках подготовки поверхности с противоречивыми результатами. Наличие противоречивых данных в научной литературе свидетельствует о необходимости изучения аспектов применения универсальных адгезивов в различных клинических ситуациях и протоколах в долгосрочной перспективе.

Ключевые слова: универсальные адгезивные системы; универсальные адгезивы; бонды для дентина; разрушение связи с тканями зуба; дентальное протравливание.

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BACKGROUND

The criteria for effective treatment of hard tooth tissues are numerous and diverse. These include restoration performance, its color and shape, marginal seal, durability, and resistance to occlusal load [1, 2].

Several factors make it difficult to provide strong adhesion between a bonding agent and hard tooth tissues. These include structural heterogeneity following preparation, hydrophilic properties of the exposed dentin surface, the presence of a smear layer, and bonding agent properties (physical and chemical properties, as well as interactions with enamel and dentin) [3].

The bond between the tooth and the filling is a critical component of a restoration. The characteristics and properties of adhesive systems determine the efficacy of treatment and the durability of results. The use of modern composite materials requires specialized skills and knowledge. The number of adhesive system components, their use, and their properties change with the evolution and modification of bonding agents, depending on the generation.

Composite materials modified with antibacterial agents or nanoparticles reduce the incidence of secondary decay [4]. However, restoration integrity is primarily determined by bonding agents. The adhesion of the filling to the tooth surface has a substantial impact on restoration durability, determining the efficacy of dental caries treatment and the subsequent prevention of complications. The quality of adhesive systems and filling materials plays a significant role in the success of enamel and dentin repair, as well as esthetic restorations. In the majority of cases, the treatment results in the restoration of destroyed tooth tissues [5].

Modern adhesive systems are important for preventing microleakages. As a result of polymerization shrinkage, a gap is formed on the filling–tooth border, which can lead to cariogenic microbial contamination and secondary decay [6].

The fifth-generation total-etch bonding agents are currently the most widely used in clinical practice. This protocol is frequently modified with moisturizers or antiseptics. This system has fewer components, is easy to use, and has over 20 years of clinical experience [7–11].

Applying self-etch bonding agents to dentin in cervical cavities (Black class V) improves the resistance to dental caries compared to preparation by total etching [12].

Universal bonding agents have significantly expanded the options for clinicians. The primary advantage of universal adhesive systems is the ability to select the etching mode (for example, self-etching or etching and washing) [13–17]. Thus, it is important to assess the efficacy of universal bonding agents in various clinical situations.

STUDY AIM: To assess the current use of universal adhesive systems in dental practice.

MATERIALS AND METHODS

The literature search was performed using PubMed, eLIBRARY.RU, and Google Scholar. The following search terms were used: *universal adhesive systems, universal adhesives, dentin bonding agents, dental debonding,* and *dental etching*. The search covered studies published during the last 10 years.

The authors used the following selection criteria for this review: original *in vitro* and *in vivo* studies assessing the efficacy and composition of bonding agents, as well as the conditions and features of using universal adhesive systems.

RESULTS

The initial search by keywords yielded 1,284 publications. After screening for compliance with search terms, 106 studies were selected. Following a full-text analysis, 31 (100%) publications were included in the review; 17 of them provided the background for this study. The data are presented in Table 1.

Fourteen (45%) studies assessed the effect of adhesive composition on adhesive strength. Eight (26%) studies assessed the adhesive strength of the bond between the tooth and the filling. The clinical application of universal bonding agents was addressed in 9 (29%) studies.

Universal bonding agents are gaining popularity due to their ease of use. The term “universal” refers to manufacturer claims that these bonding agents can be applied to the cavity surface regardless of preparation procedure; moreover, they can be used with various restoration materials [18].

According to the studies, bonding agent composition plays a critical role. Adhesive systems consist of resins containing both hydrophilic and hydrophobic monomers. Monomers in bonding agents are primarily represented by hydroxyethyl methacrylate (HEMA) and bisphenol A-glycidyl methacrylate (Bis-GMA). HEMA is a wetting agent for bonding agents that is completely miscible with water; Bis-GMA has more hydrophobic properties. It is the main monomer used in a wider range of dental bonding agents and composite materials [19]. Moreover, adhesive systems contain solvents that increase polymerized monomer infiltration into dentin tissues. Water, ethanol, acetone, and butanol can be used as solvents in universal bonding agents. Acidic hydrophilic monomers in universal bonding agents can be used on both etched enamel and non-etched surfaces contaminated with saliva or water [20]. Universal adhesive systems can include nanofillers to increase adhesion to tooth tissues and provide a more durable adhesion to dentin [21]. Several studies

Table 1. Distribution of publications by search criteria

Analyzed factor	Analyzed component	Number of publications, *n* (%)
Composition	Hydrophilic monomers Nanofillers Hydrophobic monomers Solvents Etchant	14 (45)
Adhesive strength	Surface treatment with air abrasion Smear layer characteristics Surface moisture Bonding agent type Testing conditions	8 (26)
Application method	Etching type	9 (29)

have shown that the type of nanofiller and particle incorporation method determine adhesive viscosity and the ability of monomers to infiltrate collagen fibers [22–24]. The presence or absence of specific components can influence adhesive system properties and, consequently, the durability of restorations.

K.L. Van Landuyt et al. (2008) found that a small amount (10%) of HEMA increases the adhesive strength of a single-stage self-etch bonding agent. Adhesion decreases with increased HEMA concentration; however, HEMA is highly allergenic [25].

HEMA-free adhesive systems have started to be employed in dentistry as materials have evolved. For example, A. Tsujimoto et al. (2022) tested several bonding agents, including a three-stage OptiBond FL (4th generation), a single-stage Scotchbond Universal Plus Adhesive, G2-Bond Universal (universal bonding agent), Prime&Bond NT (single-component, 5th generation), and Clearfil SE Bond 2 (6th generation). A two-stage HEMA-free universal bonding agent G2-Bond Universal demonstrated stronger adhesion to enamel and comparable or superior fatigue strength of adhesion to dentin compared to total-etch bonding agents (etching and washing). Moreover, it demonstrated comparable adhesion to enamel and a greater fatigue strength of adhesion to dentin compared to other self-etch adhesive systems (for example, Clearfil SE Bond 2 and Scotchbond Universal Plus) [26].

M.A. Munoz et al. (2015) assessed the durability of adhesive properties *in vitro* of universal bonding agents with and without MDP. Universal bonding agents containing MDP showed the greatest long-term (after 6 months of storage in water) strength of adhesion between the polymer and dentin, as well as minimized nanoleakages [27].

R. Wang (2017) assessed the characteristics of adhesion between dentin and various self-etch adhesive systems containing different functional monomers. These findings confirm that a strong chemical bond between the 10-MDP monomer and calcium hydroxyapatite increases the durability of adhesion to dentin. A functional monomer glycerophosphate dimethacrylate (GPDM), which promotes dentin etching and hydration, provides a stronger adhesion [28].

I.R. Blum et al. (2021) reported that a functional monomer 10-MDP (10-methacryloyloxydecyl dihydrogen phosphate) in adhesive systems, such as Tokuyama Bond Force II and Scotchbond Universal, increases adhesive strength in microstretching [29].

R. Pimentel de Oliveira et al. (2022) assessed the adhesive strength of HEMA- and 10-MDP-containing self-etch systems and observed higher adhesive strength compared to bonding agents containing only HEMA [30].

Numerous available studies provide conflicting data on the effect of composition and content of various functional monomers on bonding agent properties. F. Siqueira et al. (2016) assessed the strength of adhesion between universal adhesive systems and CAD/CAM materials (indirect polymer composite; feldspathic glass ceramics; leucite-reinforced glass ceramics; lithium disilicate ceramics; yttria-stabilized zirconium dioxide). The tests revealed that the chemical composition of universal bonding agents did not determine the strength of adhesion to analyzed materials. The mean adhesive strength in microdisplacement showed significant variability, depending on the material. Moreover, the authors reported improved adhesion of universal bonding agents to zirconium pretreated with air abrasion [31].

However, adhesive strength is influenced not only by adhesive system composition, but also by surface preparation and bonding agent application method.

M. Nair et al. (2014) assessed microtear strength of adhesive systems and found that an 8th generation bonding agent (Futura bond DC, Voco, Germany) had the greatest strength (34.9332 MPa) compared to 6th generation (Clearfil SE Bond, Kuraray Dental, Japan; 32.3477 MPa) and 7th generation (Adper Easy One, 3M ESPE, Germany; 31.8826 MPa) bonding agents [32].

R. Alves dos Santos et al. (2019) assessed the possibility and strength of adhesion between universal bonding agents and zirconium dioxide. Universal adhesive systems formed bonds with this material; adhesive strength increased when zirconium dioxide was pretreated with air abrasion.

P. Saikaew et al. (2016) compared the strength of adhesion to dentin treated with a bur or silicon carbide. The authors found that the adhesive strength in microstretching was greater when dentin was pretreated with silicon carbide. Treatment with a bur significantly decreased the adhesive strength [34].

According to Y. Tamura et al. (2017), air abrasion influences the adhesive strength of universal bonding agents. When assessing the strength of adhesion of universal bonding agents to dentin surface, air abrasion was associated with significantly lower adhesive strength in displacement and decreased free surface energy. Glycine powder causes less significant changes in these parameters than sodium bicarbonate [35].

C. Siriporananon et al. (2021) found that a two-stage self-etch bonding agent in combination with surface preparation using an ultra-thin diamond or carbide bur increases the adhesive strength [36].

C. Chen et al. (2015) assessed the adhesive strength in microstretching *in vitro* using five universal bonding agents (Prime&Bond Elect, Scotchbond Universal, All-Bond Universal, Clearfil Universal Bond, and Futurabond U). The authors found that both the bonding agent type and testing conditions (with or without thermocycling) have a significant impact on microstretching [37].

According to A.C. Follak (2021), the condition of dentin influences the adhesive strength. In a study in healthy bovine teeth and bovine teeth with experimentally induced caries, universal bonding agents (Scotchbond Universal Adhesive, All-Bond Universal, Prime&Bond Elect) and control bonding agents Adper Single Bond 2 (5th generation) and Clearfil SE Bond (6th generation) were used. The adhesive strength in microstretching and microleakages were assessed. When used on dentin affected by caries, all universal bonding agents showed decreased adhesive strength, regardless of the etching technique. When used on healthy dentin, decreased adhesive strength was observed with total-etch bonding agents (etching and washing). The authors concluded that universal bonding agents are unable to maintain strong adhesion to dentin affected by caries [38].

Universal adhesive systems are used with various surface preparation options, depending on the clinical situation: no etching, selective etching, or total etching of hard tooth tissues.

P. Burrer et al. (2022) assessed the effect of excessive etching and the duration of universal bonding agent application on the strength of adhesion to dentin. Human tooth samples with exposed dentin were divided into 9 groups. In the control group, phosphoric acid was used for etching (15 sec); after that, a universal bonding agent Scotchbond Universal (3M) was applied for 20 sec, according to the manufacturer's instructions. In other groups, the etching and bonding agent application times were modified. Samples were treated with a nanofilled composite material and tested for microstretching strength. When the phosphoric acid etching and bonding agent application times were reduced twofold, the adhesive strength decreased significantly compared to the control group and all other experimental groups. There were no significant differences in the adhesive strength compared to the control group, when the etching and bonding agent application times were increased to 20 sec or more. The authors concluded that the recommended time of bonding agent application to etched dentin should be at least 20 sec [39].

Using scanning electron microscopy (SEM), M. Hanabusa et al. (2012) confirmed an increase in microretention of dentin surfaces pretreated with phosphoric acid, as well as good adhesive strength, when using a single-stage self-etch bonding agent G-Bond Plus (GC, Japan; 1-SEA) [40].

T. Takamizava et al. (2016) assessed the ability of universal bonding agents to form bonds with dentin in various etching modes. It was found that the adhesive system Prime&Bond Elect (DENTSPLY Caulk, USA) had a higher fatigue strength in displacement in total etching mode than in self-etching mode. A single-stage self-etch bonding agent Clearfil Bond SE ONE [CS] (Kuraray Noritake Dental, Japan), which was used as a control, showed significantly lower values in etching and washing mode than in self-etching mode [41].

According to K. Yamauchi et al. (2019), adhesion of universal bonding agents to dentin was comparable in self-etching and total etching (etching and washing) modes [42].

S. Jacker-Guhr et al. (2019) compared the strength of adhesion of various universal bonding agents to enamel and dentin *in vitro*, with and without additional phosphoric acid etching (before and after thermocycling). The strength of adhesion of universal bonding agents to tooth tissues, especially to enamel surface, increased to 30 MPa after phosphoric acid etching [43].

T. Saito et al. (2019) assessed the effect of application time on the adhesion of universal bonding agents to dentin. In self-etching mode, all studied bonding agents (Adhese Universal (AU), Clearfil Universal Bond Quick (CQ), G-Premio Bond (GP), Scotchbond Universal (SU), and Tokuyama Universal Bond (TU)) had a higher free surface energy compared to etching and washing mode, regardless of the application time [44].

G. Cardoso de Cardoso (2019) assessed the strength of adhesion of various adhesive systems (Ambar Universal, G-Bond, Single Bond Universal, Tetric N-Bond Universal, Ybond; control group: Scotchbond Multipurpose Plus and Clearfil SE Bond) to dentin. The assessed parameters included the adhesive strength in microstretching, pH, and monomer conversion. The majority of bonding agents showed good adhesion to dentin, with a slight decrease in adhesive strength over time when using self-etching, comparable to that for gold standard bonding agents [45].

M. Kawazu et al. (2019) assessed the strength of adhesion of a universal bonding agent and two adhesive systems to dentin in etching and washing mode. Single Bond Plus (5th generation) showed a higher adhesive strength in displacement and relatively stable adhesion to dentin under all degradation conditions. The adhesive strength of a three-stage bonding agent Scotchbond Multi-Purpose Plus (4th generation) decreased with long-term degradation. The strength of adhesion of a universal adhesive system Scotchbond Universal (8th generation) to dentin showed not decrease in displacement compared to baseline under all degradation conditions [46].

G.R. Ranjitha et al. (2020) assessed the properties of a universal bonding agent G-Premio Bond with a flowing composite used for cervical defect restoration in selective etching and self-etching modes. Restoration performance was assessed in 1 week, 6 months, and 12 months. There were no significant differences in analyzed parameters between groups; however, in percentage terms, selective etching produced better results than self-etching [47]. P. Maciel Pires et al. (2022) assessed adhesion properties and ultramorphology of the polymer–dentin interface of modern universal bonding agents (ZipBond, Prime and Bond Active, Clearfil Universal Bond Quick, Scotchbond Universal). Each adhesive system was used in two modes: self-etching mode and etching and washing mode. The study found that adhesive strength depends on the used adhesion strategy. The self-etching mode provided the best adhesion to dentin [48].

CONCLUSION

Universal adhesive systems have a wide range of clinical applications (various methods of surface preparation) and clinical scenarios, expanding their potential use. The findings of the literature review describe various applications of universal adhesive systems with various surface preparation techniques, with mixed results. Conflicting literature data highlight the importance of investigating the long-term use of universal bonding agents with various clinical settings and protocols.

ADDITIONAL INFORMATION

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REFERENCES

1. Rizzante FAP, Mondelli RFL, Furuse AY, et al. Shrinkage stress and elastic modulus assessment of bulk-fill composites. *J Appl Oral Sci.* 2019;27:e20180132. doi: 10.1590/1678-7757-2018-0132

2. Razumova SN, Gapochkina LL, Bragunova RM, et al. Estimation of antimicrobial additive influence on composite properties. *Medical Alphabet.* 2017;4(36):24–27. EDN: YNMLZS

3. Aslanjan MA, Eremin OV, Trufanova JJ. Application of adhesive systems in dentistry: past and present. *Saratov Scientific and Medical Journal.* 2018;14(2):234–239. EDN: YBSLZR

4. Bragunova RM, Razumova SN, Melkumyan AR, et al. Study of antimicrobial activity of composite materials. *Medical Alphabet.* 2018;1(2(339)):54–58. EDN: XPLEEX

5. Razumova SN, Brago AS, Khaskhanova LM et al. Modern methods of prevention of dental diseases. *Medical Alphabet.* 2018;3(24(361)):69–70. EDN: VWQGCH

6. Bragunova RM, Razumova SN, Volina EG. Adhesive activity of cariesogenic microorganisms to composite material with antibacterial additive. *Medical Alphabet.* 2018;3(24(361)):26–27. EDN: YPUTBR

7. Khaskhanova LM, Razumova SN, Gapochkina LL, et al Comparative characteristics of the strength of adhesive systems of the fifth generation in the modification of the adhesive protocol. Medical Alphabet. 2022;(2):63–66. doi: 10.33667/2078-5631-2022-2-63-66

8. Khashanova LM, Razumova SN, Brago AS, et al. Comparative characteristics of physical and mechanical properties of adhesive systems. *J Int Dent Med Res.* 2022;15(1):27–30.

9. Khaskhanova LM, Razumova SN, Serebrov DM, et al. Scanning Electron Microscopy. *J Int Dent Med Res.* 2022;15(1):107–109.

10. Khaskhanova LM, Razumova SN, Brago AS, et al. The effectiveness of the use of fifth-generation adhesive systems if changing the protocol before and after thermal cycling. *Medical Alphabet.* 2022;(7):55–59. doi: 10.33667/2078-5631-2022-7-55-59

11. Khaskhanova LM, Razumova SN, Brago AS, et al. The effectiveness of the use of fifth-generation adhesive systems if changing the protocol before and after thermal cycling. *Medical Alphabet.* 2022;(7):63–67. doi: 10.33667/2078-5631-2022-7-55-59

12. Bakry AS, Abbassy MA. Application modes affect two universal adhesive systems' nanoleakage expression and shear bond strength. *Biomed Res Int.* 2021;2021:7375779. doi: 10.1155/2021/7375779

13. Hass V, Cardenas A, Siqueira F, et al. Bonding performance of universal adhesive systems applied in etch-and-rinse and self-etch strategies on natural dentin caries. *Oper Dent.* 2019;44(5):510–520. doi: 10.2341/17-252-L

14. Loguercio AD, de Paula EA, Hass V, et al. A new universal simplified adhesive: 36-month randomized double-blind clinical trial. *J Dentistry.* 2015;43(9):1083–1092. doi: 10.1016/j.jdent.2015.07.005

15. Munoz MA, Luque I, Hass V, et al. Immediate bonding properties of universal adhesives to dentine. *Journal of Dentistry.* 2013;41(5):404–411. doi: 10.1016/j.jdent.2013.03.001

16. Munoz MA, Luque-Martinez I, Malaquias P, et al. In vitro longevity of bonding properties of universal adhesives to dentin. *Operative Dentistry.* 2015;40(3):282–292. doi: 10.2341/14-055-L

17. Sezinando A, Luque-Martinez I, Munoz MA, et al. Influence of a hydrophobic resin coating on the immediate and 6-month dentin bonding of three universal adhesives. *Dental Materials.* 2015;31(10):e236–e246. doi: 10.1016/j.dental.2015.07.002

18. Nagarkar S, Theis-Mahon N, Perdigão J. Universal dental adhesives: Current status, laboratory testing, and clinical performance. *J Biomed Mater Res B Appl Biomater.* 2019;107(6):2121–2131. doi: 10.1002/jbm.b.34305

19. Sideridou I, Tserki V, Papanastasiou G. Study of water sorption, solubilità and modulus of elasticity of light-cured dimethacrylate-based dental resins. *Biomaterials.* 2003;24:655–665. doi: 10.1016/s0142-9612(02)00380-0

20. Karami Nogourani M, Javadi Nejad Sh, Homayunzadeh M. Sealant Microleakage in Saliva-Contaminated Enamel: Comparison between three adhesive systems. *J Dent Sch.* 2010;27(4):197–204.

21. Nair M, Paul J, Kumar S. Comparative evaluation of the bonding efficacy of sixth and seventh generation bonding agents: An In-Vitro study. *J Conserv Dent.* 2014;17(1):27–30. doi: 10.4103/0972-0707.124119

22. Başaran G, Ozer T, Devecioğlu Kama J. Comparison of a recently developed nanofiller self-etching primer adhesive with other self-etching primers and conventional acid etching. *Eur J Orthod.* 2009;31(3):271–275. doi: 10.1093/ejo/cjn103

23. Kasraei SH, Atai M, Khamverdi Z, Khalegh Nejad S. Effect of nanofiller addition to an experimental dentin adhesive on microtensile bond strength to human dentin. *J Dent (Tehran)* 2009;6(2):91–96.

24. Sofan E, Sofan A, Palaia G, et al. Classification review of dental adhesive systems: from the IV generation to the universal type. *Ann Stomatol (Roma).* 2017;8(1):1–17. doi: 10.11138/ads/2017.8.1.001

25. Van Landuyt KL, Snauwaert J, Peumans M, et al. The role of HEMA in one-step self-etch adhesives. *Dent Mater.* 2008;24(10):1412–1419. doi: 10.1016/j.dental.2008.02.018

26. Tsujimoto A, Fischer NG, Barkmeier WW, Latta MA. Bond Durability of Two-Step HEMA-Free Universal Adhesive. *J Funct Biomater.* 2022;13(3):134. doi: 10.3390/jfb13030134

27. Muñoz MA, Luque-Martinez I, Malaquias P, et al. In vitro longevity of bonding properties of universal adhesives to dentin. *Oper Dent.* 2015;40(3):282–292. doi: 10.2341/14-055-L

28. Wang R, Shi Y, Li T, et al. Adhesive interfacial characteristics and the related bonding performance of four self-etching adhesives with different functional monomers applied to dentin. *J Dent.* 2017;62:72–80. doi: 10.1016/j.jdent.2017.05.010

29. Blum IR, Martos R, Szalóki M, et al. Effects of different surface treatments and adhesive self-etch functional monomers on the repair of bulk fill composites: A randomised controlled study. *J Dent.* 2021;108:103637. doi: 10.1016/j.jdent.2021.103637

30. Pimentel de Oliveira R, de Paula BL, Ribeiro ME, et al. Evaluation of the Bond Strength of Self-Etching Adhesive Systems Containing HEMA and 10-MDP Monomers: Bond Strength of Adhesives Containing HEMA and 10-MD. *Int J Dent.* 2022;2022:5756649. doi: 10.1155/2022/5756649

31. Siqueira F, Cardenas AM, Gutierrez MF, et al. Laboratory Performance of Universal Adhesive Systems for Luting CAD/CAM Restorative Materials. *J Adhes Dent.* 2016;18(4):331–40. doi: 10.3290/j.jad.a36519

32. Nair M, Paul J, Kumar S, et al. Comparative evaluation of the bonding efficacy of sixth and seventh generation bonding agents: An In-Vitro study. *J Conserv Dent.* 2014;17(1):27–30. doi: 10.4103/0972-0707.124119

33. Dos Santos RA, de Lima EA, Mendonça LS, et al. Can universal adhesive systems bond to zirconia? *J Esthet Restor Dent.* 2019;31(6):589–594. doi: 10.1111/jerd.12521

34. Saikaew P, Chowdhury AF, Fukuyama M, et al. The effect of dentine surface preparation and reduced application time of adhesive on bonding strength. *J Dent.* 2016;47:63–70. doi: 10.1016/j.jdent.2016.02.001

35. Tamura Y, Takamizawa T, Shimamura Y, et al. Influence of air-powder polishing on bond strength and surface-free energy of universal adhesive systems. *Dent Mater J.* 2017;36(6):762–769. doi: 10.4012/dmj.2016-185

36. Siriporananon C, Senawongse P, Sattabanasuk V, et al. Effects of dentin surface preparations on bonding of self-etching adhesives under simulated pulpal pressure. *Restor Dent Endod.* 2021;47(1):e4. doi: 10.5395/rde.2022.47.e4

37. Chen C, Niu LN, Xie H, et al. Bonding of universal adhesives to dentine-Old wine in new bottles? *J Dent.* 2015;43(5):525–536. doi: 10.1016/j.jdent.2015.03.004

38. Follak AC, Miotti LL, Lenzi TL, et al. Self-etch approach of universal adhesives as an alternative to minimize bond degradation on sound dentin vs caries-affected dentin over time. *J Adhes Dent.* 2021;23(3):243–252. doi: 10.3290/j.jad.b1367889

39. Burrer P, Dang H, Par M, et al. Effect of over-etching and prolonged application time of a universal adhesive on dentin bond strength. *Polymers (Basel).* 2020;12(12):2902. doi: 10.3390/polym12122902

40. Hanabusa M, Mine A, Kuboki T, et al. Bonding effectiveness of a new 'multi-mode' adhesive to enamel and dentine. *J Dent.* 2012;40(6):475–484. doi: 10.1016/j.jdent.2012.02.012

41. Takamizawa T, Barkmeier WW, Tsujimoto A, et al. Influence of different etching modes on bond strength and fatigue strength to dentin using universal adhesive systems. *Dent Mater.* 2016;32(2):e9–21. doi: 10.1016/j.dental.2015.11.005

42. Yamauchi K, Tsujimoto A, Jurado CA, et al. Etch-and-rinse vs self-etch mode for dentin bonding effectiveness of universal adhesives. *J Oral Sci.* 2019;61(4):549–553. doi: 10.2334/josnusd.18-0433

43. Jacker-Guhr S, Sander J, Luehrs AK. How "Universal" is Adhesion? Shear Bond Strength of Multi-mode Adhesives to Enamel and Dentin. *J Adhes Dent.* 2019;21(1):87–95. doi: 10.3290/j.jad.a41974

44. Saito T, Takamizawa T, Ishii R. Influence of application time on dentin bond performance in different etching modes of universal adhesives. *Oper Dent.* 2020;45(2):183–195. doi: 10.2341/19-028-L

45. Cardoso GC, Nakanishi L, Isolan CP, et al. Bond stability of universal adhesives applied to dentin using etch-and-rinse or self-etch strategies. *Braz Dent J.* 2019;30(5):467–475. doi: 10.1590/0103-6440201902578

46. Kawazu M, Takamizawa T, Hirokane E, et al. Comparison of dentin bond durability of a universal adhesive and two etch-and-rinse adhesive systems. *Clin Oral Investig.* 2020;24(8):2889–2897. doi: 10.1007/s00784-019-03153-y

47. Ranjitha GR, Vikram R, Meena N, et al. Clinical efficacy of universal adhesives for the restoration of noncarious cervical lesions: A randomized clinical trial. *J Conserv Dent.* 2020;23(3):227–232. doi: 10.4103/JCD.JCD_51_20

48. Maciel Pires P, Dávila-Sánchez A, Faus-Matoses V, et al. Bonding performance and ultramorphology of the resin-dentine interface of contemporary universal adhesives. *Clin Oral Investig.* 2022;26(6):4391–4405. doi: 10.1007/s00784-022-04402-3

СПИСОК ЛИТЕРАТУРЫ

1. Rizzante F.A.P., Mondelli R.F.L., Furuse AY., et al. Shrinkage stress and elastic modulus assessment of bulk-fill composites // J Appl Oral Sci. 2019. Vol. 27. P. e20180132. doi: 10.1590/1678-7757-2018-0132

2. Разумова С.Н., Гапочкина Л.Л., Брагунова Р.М., и др. Оценка влияния антимикробной добавки на свойства композита // Медицинский алфавит. 2017. Т. 4, № 36(333). С. 24–27. EDN: YNMLZS

3. Асланян М.А., Еремин О.В., Труфанова Ю.Ю., и др. Применение адгезивных систем в стоматологии: прошлое и настоящее // Саратовский научно-медицинский журнал. 2018. Т. 14, № 2. С. 234–239. EDN: YBSLZR

4. Брагунова Р.М., Разумова С.Н., Мелкумян А.Р., и др. Изучение антимикробной активности композитных материалов // Медицинский алфавит. 2018. Т. 1, № 2(339). С. 54–58. EDN: XPLEEX

5. Разумова С.Н., Браго А.С., Хасханова Л.М., и др. Современные методы профилактики стоматологических заболеваний // Медицинский алфавит. 2018. Т. 3, № 24(361). С. 69–70. EDN: VWQGCH

6. Брагунова Р.М., Разумова С.Н., Волина Е.Г. Адгезивная активность кариесогенных микроорганизмов к образцам композитного материала с антибактериальной добавкой // Медицинский алфавит. 2018. Т. 3, № 24(361). С. 26–27. EDN: YPUTBR

7. Хасханова Л.М., Разумов С.Н., Гапочкина Л.Л., и др. Сравнительная характеристика адгезивной прочности адгезивных систем пятого поколения при модификации адгезивного протокола // Медицинский алфавит. 2022. № 2. С. 63–66. doi: 10.33667/2078-5631-2022-2-63-66

8. Khashanova L.M., Razumova S.N., Brago A.S., et al. Comparative characteristics of physical and mechanical properties of adhesive systems // J Int Dent Med Res. 2022. Vol. 15, N. 1. P. 27–30.

9. Khaskhanova L.M, Razumova S.N., Serebrov D.M., et al. Scanning Electron Microscopy // J Int Dent Med Res. 2022. Vol. 15, N. 1. P. 107–109.

10. Хасханова Л.М., Разумова С.Н., Браго А.С., и др. Эффективность применения адгезивных систем пятого поколения при изменении протокола до и после термоциклирования. // Медицинский алфавит. 2022. № 7. С. 55–59. doi: 10.33667/2078-5631-2022-7-55-59

11. Хасханова Л.М., Разумова С.Н., Гапочкина Л.Л., и др. Сравнительная характеристика адгезивной прочности адгезивных систем пятого поколения при модификации адгезивного протокола // Медицинский алфавит. 2022. № 7. С. 63–67. doi: 10.33667/2078-5631-2022-2-63-66

12. Bakry A.S., Abbassy M.A. Application modes affect two universal adhesive systems' nanoleakage expression and shear bond strength // Biomed Res Int. 2021. Vol. 2021. P. 7375779. doi: 10.1155/2021/7375779

13. Hass V., Cardenas A., Siqueira F., et al. Bonding performance of universal adhesive systems applied in etch-and-rinse and self-etch strategies on natural dentin caries. // Oper Dent. 2019. Vol. 44, N. 5. P. 510–520. doi: 10.2341/17-252-L

14. Loguercio A.D., de Paula E.A., Hass V., et al. A new universal simplified adhesive: 36-month randomized double-blind clinical trial // J Dentistry. 2015. Vol. 43, N. 9. P. 1083–1092. doi: 10.1016/j.jdent.2015.07.005

15. Munoz M.A., Luque I., Hass V., et al. Immediate bonding properties of universal adhesives to dentine // J Dentistry. 2013. Vol. 41, N. 5. P. 404–411. doi: 10.1016/j.jdent.2013.03.001

16. Munoz M.A., Luque-Martinez I., Malaquias P., et al. In vitro longevity of bonding properties of universal adhesives to dentin // Oper Dentistry. 2015. Vol. 40, N. 3. P. 282–292. doi: 10.2341/14-055-L

17. Sezinando A., Luque-Martinez I., Munoz M.A., et al. Influence of a hydrophobic resin coating on the immediate and 6-month dentin bonding of three universal adhesives // Dental Materials. 2015. Vol. 31, N. 10. P. e236–e246. doi: 10.1016/j.dental.2015.07.002

18. Nagarkar S., Theis-Mahon N., Perdigão J. Universal dental adhesives: Current status, laboratory testing, and clinical performance // J Biomed Mater Res B Appl Biomater. 2019. Vol. 107, N. 6. P. 2121–2131. doi: 10.1002/jbm.b.34305

19. Sideridou I., Tserki V., Papanastasiou G. Study of water sorption, solubilità and modulus of elasticity of light-cured dimethacrylate-based dental resins. Biomaterials. 2003. Vol. 24. P. 655–665 doi: 10.1016/s0142-9612(02)00380-0

20. Karami Nogourani M., Javadi Nejad Sh., Homayunzadeh M. Sealant Microleakage in Saliva-Contaminated Enamel: Comparison

between three adhesive systems // J Dent Sch. 2010. Vol. 27, N. 4. P. 197–204.
21. Nair M., Paul J., Kumar S. Comparative evaluation of the bonding efficacy of sixth and seventh generation bonding agents: An In-Vitro study // J Conserv Dent. 2014 Jan. Vol. 17, N. 1. P. 27–30. doi: 10.4103/0972-0707.124119
22. Başaran G., Ozer T., Devecioğlu Kama J. Comparison of a recently developed nanofiller self-etching primer adhesive with other self-etching primers and conventional acid etching // Eur J Orthod. 2009. Vol. 31, N. 3. P. 271–275. doi: 10.1093/ejo/cjn103
23. Kasraei S.H., Atai M., Khamverdi Z., Khalegh Nejad S. Effect of nanofiller addition to an experimental dentin adhesive on microtensile bond strength to human dentin // J Dent (Tehran) 2009. Vol. 6, N. 2. P. 91–96.
24. Sofan E., Sofan A., Palaia G., et al. Classification review of dental adhesive systems: from the IV generation to the universal type // Ann Stomatol (Roma). 2017. Vol. 8, N. 1. P. 1–17. doi: 10.11138/ads/2017.8.1.001
25. Van Landuyt K.L., Snauwaert J., Peumans M., et al. The role of HEMA in one-step self-etch adhesives // Dent Mater. 2008. Vol. 24, N. 10. P. 1412–1419. doi: 10.1016/j.dental.2008.02.018
26. Tsujimoto A., Fischer N.G., Barkmeier W.W., Latta M.A. Bond Durability of Two-Step HEMA-Free Universal Adhesive // J Funct Biomater. 2022. Vol. 13, N. 3. P. 134. doi: 10.3390/jfb13030134
27. Muñoz M.A., Luque-Martinez I., Malaquias P., et al. In vitro longevity of bonding properties of universal adhesives to dentin // Oper Dent. 2015. Vol. 40, N. 3. P. 282–292. doi: 10.2341/14-055-L
28. Wang R., Shi Y., Li T., et al. Adhesive interfacial characteristics and the related bonding performance of four self-etching adhesives with different functional monomers applied to dentin // J Dent. 2017. Vol. 62. P. 72–80. doi: 10.1016/j.jdent.2017.05.010
29. Blum I.R., Martos R., Szalóki M., et al. Effects of different surface treatments and adhesive self-etch functional monomers on the repair of bulk fill composites: A randomised controlled study // J Dent. 2021. Vol. 108. P. 103637. doi: 10.1016/j.jdent.2021.103637
30. Pimentel de Oliveira R., de Paula B.L, Ribeiro M.E., et al. Evaluation of the Bond Strength of Self-Etching Adhesive Systems Containing HEMA and 10-MDP Monomers: Bond Strength of Adhesives Containing HEMA and 10-MD // Int J Dent. 2022. Vol. 2022. P. 5756649. doi: 10.1155/2022/5756649
31. Siqueira F., Cardenas A.M., Gutierrez M.F., et al. Laboratory Performance of Universal Adhesive Systems for Luting CAD/CAM Restorative Materials // J Adhes Dent. 2016. Vol. 18, N. 4. P. 331–340. doi: 10.3290/j.jad.a36519
32. Nair M., Paul J., Kumar S., et al. Comparative evaluation of the bonding efficacy of sixth and seventh generation bonding agents: An In-Vitro study // J Conserv Dent. 2014. Vol. 17, N. 1. P. 27–30. doi: 10.4103/0972-0707.124119
33. Dos Santos R.A., de Lima E.A., Mendonça L.S., et al. Can universal adhesive systems bond to zirconia? // J Esthet Restor Dent. 2019. Vol. 31, N. 6. P. 589–594. doi: 10.1111/jerd.12521
34. Saikaew P., Chowdhury A.F., Fukuyama M., et al. The effect of dentine surface preparation and reduced application time of adhesive on bonding strength // J Dent. 2016. Vol. 47. P. 63–70. doi: 10.1016/j.jdent.2016.02.001
35. Tamura Y., Takamizawa T., Shimamura Y., et al. Influence of air-powder polishing on bond strength and surface-free energy of universal adhesive systems // Dent Mater J. 2017. Vol. 36, N. 6. P. 762–769. doi: 10.4012/dmj.2016-185
36. Siriporananon C., Senawongse P., Sattabanasuk V., et al. Effects of dentin surface preparations on bonding of self-etching adhesives under simulated pulpal pressure // Restor Dent Endod. 2021. Vol. 47, N. 1. P. e4. doi: 10.5395/rde.2022.47.e4
37. Chen C., Niu L.N., Xie H., et al. Bonding of universal adhesives to dentine--Old wine in new bottles? // J Dent. 2015. Vol. 43, N. 5. P. 525–536. doi: 10.1016/j.jdent.2015.03.004
38. Follak A.C., Miotti L.L., Lenzi T.L., et al Self-etch approach of universal adhesives as an alternative to minimize bond degradation on sound dentin vs caries-affected dentin over time. J Adhes Dent. 2021. Vol. 23, N. 3. P. 243–252. doi: 10.3290/j.jad.b1367889
39. Burrer P., Dang H., Par M., et al. Effect of over-etching and prolonged application time of a universal adhesive on dentin bond strength // Polymers (Basel). 2020. Vol. 12, N. 12. P. 2902. doi: 10.3390/polym12122902
40. Hanabusa M., Mine A., Kuboki T., et al. Bonding effectiveness of a new ‘multi-mode’ adhesive to enamel and dentine // J Dent. 2012. Vol. 40, N. 6. P. 475–484. doi: 10.1016/j.jdent.2012.02.012
41. Takamizawa T., Barkmeier W.W., Tsujimoto A., et al. Influence of different etching modes on bond strength and fatigue strength to dentin using universal adhesive systems // Dent Mater. 2016. Vol. 32, N. 2. P. e9–21. doi: 10.1016/j.dental.2015.11.005
42. Yamauchi K., Tsujimoto A., Jurado C.A., et al. Etch-and-rinse vs self-etch mode for dentin bonding effectiveness of universal adhesives // J Oral Sci. 2019 Nov 27. Vol. 61, N. 4. P. 549–553. doi: 10.2334/josnusd.18-0433
43. Jacker-Guhr S., Sander J., Luehrs A.K. How “Universal” is Adhesion? Shear Bond Strength of Multi-mode Adhesives to Enamel and Dentin // J Adhes Dent. 2019. Vol. 21, N. 1. P. 87–95. doi: 10.3290/j.jad.a41974
44. Saito T., Takamizawa T., Ishii R. Influence of application time on dentin bond performance in different etching modes of universal adhesives // Oper Dent. 2020. Vol. 45, N. 2. P. 183–195. doi: 10.2341/19-028-L
45. Cardoso G.C., Nakanishi L., Isolan C.P., et al. Bond stability of universal adhesives applied to dentin using etch-and-rinse or self-etch strategies // Braz Dent J. 2019. Vol. 30, N. 5. P. 467–475. doi: 10.1590/0103-6440201902578
46. Kawazu M., Takamizawa T., Hirokane E., et al. Comparison of dentin bond durability of a universal adhesive and two etch-and-rinse adhesive systems // Clin Oral Investig. 2020. Vol. 24, N. 8. P. 2889–2897. doi: 10.1007/s00784-019-03153-y
47. Ranjitha G.R., Vikram R., Meena N., et al. Clinical efficacy of universal adhesives for the restoration of noncarious cervical lesions: A randomized clinical trial // J Conserv Dent. 2020. Vol. 23, N. 3. P. 227–232. doi: 10.4103/JCD.JCD_51_20
48. Maciel Pires P., Dávila-Sánchez A., Faus-Matoses V., et al. Bonding performance and ultramorphology of the resin-dentine interface of contemporary universal adhesives // Clin Oral Investig. 2022. Vol. 26, N. 6. P. 4391–4405. doi: 10.1007/s00784-022-04402-3

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