Revista ARACÊ
ISSN: 2358-2472

EVOLUTION OF DENTIN ADHESIVES: LITERATURE REVIEW

https://doi.org/10.56238/arev6n2-194

Submitted on: 28/09/2024 **Publication date:** 28/10/2024

Ana Beatriz Cesnik Cardoso[1], Ellen Thaily Modos de Faria[2], Celine Garcia[3], Amanda Beatriz Casu Ribeiro[4], Cláudio Alberto Franzin[5], Lucimara Cheles da Silva Franzin[6], Sandra de Oliveira Torchi[7] and Ilma Carla de Souza[8]

ABSTRACT
The aesthetic demand has culminated in the improvement of restorative dentistry through new products, such as dentin adhesives, so commonly used in current restorative procedures. The quality of the union of the restorative material with the dental substrate is essential for the longevity of the treatment; In this way, dentin adhesives with different compositions are marketed, aiming to achieve optimal adhesion. The present study aimed to review the literature on the evolution of dentin adhesives, since research can bring to light innovations that overcome the limitations of contemporary adhesive systems. This article shows the evolution of dentin adhesives, their efficacy, and clinical relevance. Knowing new dentin adhesives, techniques and care required before and during the application of the chosen adhesive contributes to increasing the durability of adhesive restorations, in order to ensure satisfactory results in the union between the resin and the dental substrate, avoiding the repetitive restorative cycle.

Keywords: Dentin Adhesives. Nanotechnology. Composite Resins.

[1] Undergraduate Student in Dentistry
Ingá University Center (UNINGÁ)
[2] Undergraduate Student in Dentistry
Ingá University Center (UNINGÁ)
[3] Undergraduate Student in Dentistry
Ingá University Center (UNINGÁ)
[4] Undergraduate Student in Dentistry
Ingá University Center (UNINGÁ)
[5] Master's student in Dentistry
Ingá University Center (UNINGÁ)
[6] Post-Doctorate in Dentistry (UEM)
Lecturer - Ingá University Center (UNINGÁ)
[7] Master in Orthodontics (UNINGÁ)
Lecturer - Ingá University Center (UNINGÁ)
[8] Guidance counselor
Post-Doctorate in Dentistry (UEM)
Lecturer - Ingá University Center (UNINGÁ)
E-mail: ilmacarlaics@gmail.com

Revista ARACÊ
ISSN: 2358-2472

INTRODUCTION

Adhesive systems are indispensable materials in everyday dental life, used mainly in composite resin restorations and ceramic cementations (MALETIN *et al*., 2023). The dental adhesive has the function of promoting the union between the resinous material and the dental substrate, which is crucial for the longevity and clinical success of current restorative procedures (CARDOSO *et al*., 2023).

Given the importance of the bond between materials and the dental substrate, it is essential to understand the evolution, innovations, and techniques associated with adhesive systems (**PERDIGÃO *et al*. 2020).** Constant technological innovations, such as the emergence of self-etching adhesives, as well as the inclusion of nanoparticles, can transform the effectiveness of dental treatments, however, they require new research and discussions (CARDOSO *et al*., 2023).

Some authors have revolutionized aesthetic and restorative dentistry (KULSHRESTHA, 2023); such as Hagger (1951), who developed the first dental adhesive called "Sevriton Cavity Seal", composed of glycerophosphoric acid dimethacrylate (GPDM), with chemical bonding to the calcium found in the tooth structure, which bonded acrylic resins to the tooth structure; Buonocore (1955), who advocated the acid etching of enamel with 85% phosphoric acid, considered a pioneer in adhesive dentistry; followed by Bowen (1965), who developed the monomer Bis-GMA (bisphenol glycidyl methacrylate), still used in most of today's composite resins. Furthermore, a milestone in adhesive dentistry was the study by Nakabayashi and Masuhara (1982), describing the adhesion process, as the replacement of minerals removed from hard dental tissues by resin monomers, in such a way that the polymer became micromechanically interconnected to the dental substrate, forming what is called a hybrid layer, by the infiltration of monomers into the matrix of demineralized dentin collagen (KOKOL, 2020).

The formation of a hybrid layer between the adhesive and the dentin is crucial for the survival of composite resin restorations (BRESCHI *et al*., 2023); this layer is formed in two steps: the first step includes the conditioning of the dentin, usually with phosphoric acid (35–37%) for 15 seconds (conditioning and washing adhesive systems), which removes calcium phosphates, leading to the formation of micropores in the dentin substrate and exposure of the collagen scaffold; and, the second step involves penetrating the adhesive monomers into the exposed network of collagen fibrils, providing micromechanical retention (REY *et al*., 2022). These monomers, which contain hydrophilic and hydrophobic groups,

Revista ARACÊ
ISSN: 2358-2472

penetrate the embouchures and bind to collagen fibers, controlling moisture (NAKABAYASHI *et al*. 1982; YOSHIHARA *et al*. 2021).

The first phosphonated adhesive was Clearfil-Bond (Kuraray Noritake Dental Inc., Tokyo, Japan, 1976), the phosphate group has an acidic character and gives it the ability to chemically bond to mineralized dental substrates and metal oxides, through an ionic bond to calcium (PASHLEY *et al*., 2023); in 1991, Prisma Universal Bond 3 was launched by Caulk (LD Caulk Co.), in addition to new adhesives with high success rates due to increased bond strength (ALAM *et al*., 2023).

The introduction of 10-methacryloyloxydecyl dihydrogen phosphate (MDP) into self-etching adhesive systems is particularly noted for its ability to bond with hydroxyapatite, contributing to stable and durable adhesion (FEHRENBACH et al., 2021).

Currently, researchers face challenges to develop dentin adhesives that not only bind to the dental substrate, but also contain antibacterial, remineralizing, and enzyme inhibitory properties that increase its longevity (MARTINS *et al*., 2014; FERNANDES, 2021).

The advances in nanotechnology in the area of health, biomaterials, and biotechnology have been eloquent in recent decades, giving rise to the creation of a new field of study, called nanomedicine (ROSA *et al*., 2023). In 2010, self-etching adhesive systems were introduced to the market by the Voco Company that contain nanofiller (12 nm) these components increase the penetration of monomers in the hybrid layer and their mechanical properties (HUANG *et al*., 2022).

In the area of restorative dentistry, the use of nanotechnology and dental biomaterials aims to optimize the physical properties and contribute to the quality of restorative and preventive materials such as nanocomposites, nano-adhesives, nano-CIV, nano-varnish and nano-sealants (FREIRE *et al*., 2019; LIMA *et al.,* 2021). The incorporation of nanoparticles in the adhesive systems improved the penetration into the tubules of the dentinary, increasing the contact area and reinforcing the mechanical properties of the restorations (ARDILA *et al.,* 2023).

The objective of this study was to compile data regarding the implications of the evolution of dentin adhesives in dentistry, and their impact on the durability and results of adhesive procedures.

MATERIAL AND METHODS

Considering the planned objectives, a broad search of scientific articles was carried out centered on the proposed theme: "Advances in adhesive systems and their different compositions". This research involved exploring multiple relevant websites and platforms, known for disseminating quality scientific information about the field of dental adhesives. Among the main sources consulted, Google Scholar, the PubMed database, the *Scientific Electronic Library Online* (SciELO) and Elsevier stood out. The electronic search and selection of articles began in April 2024, with the collection of data and information relevant to the topic. The selection of articles was meticulously carried out, ensuring that the contents found corresponded to the questions formulated.

To refine the search, specific inclusion criteria were established, consisting of the choice of articles that presented full texts, as well as course, master's, and doctoral conclusion papers, published between 2007 and 2024. There was no distinction between languages, allowing a more comprehensive approach to the topic. With this systematic approach, the research aimed not only to compile information, but also to critically analyze the advances in adhesive systems, contributing to the understanding of the different compositions and their applications in modern dentistry.

RESULTS AND DISCUSSION

Among the possible causes of adhesive bond failure, inadequate acid conditioning, lack of operator experience, and incorrect technique execution and selection can be mentioned (SANCHES *et al*., 2023). Acid etching in the enamel generates the removal of minerals by creating microporosities that allow infiltration by resinous and hydrophobic monomers present in the adhesive, forming resin tags, providing effective adhesion and longevity of the restoration (VAN MEERBEEK *et al*., 2020).

Several researchers indicate a modification in the application protocols of adhesive systems, aiming to reduce the degradation of the adhesive interface (PEUMANS *et al*., 2021). This ranges from the force applied during the use of the adhesive system to the adoption of chlorhexidine to the dentin substrate after acid etching, aiming to improve the conditions of infiltration of the adhesive into the dentin and to increase the resistance of collagen fibrils to enzymatic degradation (BOURGI *et al*., 2024). Medeiros *et al*. (2019), highlight the importance of chlorhexidine after acid etching of the dentin, to achieve a longer-lasting adhesion between the dentin and the composite resin; however, for Boaru *et*

Revista ARACÊ
ISSN: 2358-2472

al. (2023), pretreatment with chlorhexidine does not affect the quality of the hybrid layer, regardless of the conditioning protocol.

According to Rodrigues (2021), in dentin, adhesion is hindered by the organic composition of the substrate, the moisture of the dentin tubules, and the presence of *smear plug* (dirt inside the dentin tubules). According to Froehlich *et al*., (2021) and Oliveira *et al*., (2010), etching with phosphoric acid in dentin should completely remove the dentin smear layer, as well as promote the demineralization and exposure of collagen fibers, allowing efficient hybridization, where the conditioned dentin is kept moist, with the presence of water in the collagen fibers, the keeps them expanded, preserving the interfibrillary spaces.

At present, adhesive systems can be classified according to the adhesion strategy to dental tissues, being conventional adhesives, which require prior conditioning of surfaces with 37% phosphoric acid, or self-etching adhesives, which do not require prior acid conditioning and adhesion to dental tissues through *acid* primers (AHMED *et al*., 2020; RODRIGUES *et al.,* 2021).

According to Silva *et al*., (2022), conventional adhesives need the demineralization of enamel and dentin with the application of phosphoric acid generally used at a concentration of 37% as a step independently and prior to the *primer* and adhesive, creating more porosities on the enamel surface, increasing both the adhesion area and the wettability of the substrate.

Furthermore, Al-Ani *et al*. (2022) report that despite the difficulty of the technique, the conventional 3-step adhesive was considered the gold standard for adhesion and proved to be superior to the 2-step adhesive, a fact justified by Pashley, *et al*. (2020), given that, in dentin, adhesion presents difficulties, such as the organic composition of the substrate, the moisture contained in the dentin tubules and the presence of the *smear layer*, removed in the presence of acid; thus, acid etching creates an ideal surface for adhesion, making it long-lasting and reliable (KUBO *et al.* 2021)element.

In the literature, the introduction of the monomer The monomer 10-methacryloyloxydecyl dihydrogen phosphate (MDP) monomer is used in dentin adhesives due to its ability to form stable chemical bonds with calcium ions from hydroxyapatite, playing an important role in self-etching adhesive systems and in some conventional ones (Takahashi *et al*., 2021). Although self-etching adhesives have been developed to optimize work time, simplifying the adhesion technique to dentin, since the technique does not require the prior and isolated application of phosphoric acid, for Van Meerbeek *et al*. (2020), the technique is less effective in creating microporosities in tooth enamel, resulting in inferior adhesion. However, **Yoshihara *et al*. (2018), reports that** the acidic character of its *primer* and partial demineralization creates a porosity on the surface, sufficient to obtain the micromechanical embryonic of the resin monomers, ensuring hybridization, in addition, they do not remove the *smear layer* and, therefore, have less postoperative sensitivity (LIU *et al*., 2022).

According to Lorenzetti *et al*., (2019) and Yoshihara *et al*., (2021), the universal adhesive can be used as a self-etching or conventional adhesive, where selective acid conditioning of enamel can also be employed to enhance the quality of the bond and tends to reduce the risk of sensitivity after the procedure. Some nanoparticles were increased because they improved the physical, mechanical and optical properties of the resin composites, improving the penetration into the dentin tubules, increasing the contact area and, consequently, the mechanical resistance of the restorations; however, in addition to the benefits, the authors report that nanomaterials they can be absorbed through the skin and trigger inflammation of the alveoli, myocardial infarction, and other inflammations (TAY *et al.,* 2022)

According to Lima *et al*., (2021), the applicability of nanotechnology and dental bionanomaterials aims to improve physical properties and improve tooth restoration, thus, nanocomposites, dental nanoadhesives, nano-CIV (glass ionomer cement), nano-varnish and nano-sealants were researched and developed. According to Huang *et al*., (2022), nanocomposites can be categorized into composite resins and dental adhesives, in addition, for the elaboration of nanocomposites there are three main challenges: the prevention of the formation of secondary caries, a good adhesive system and the prevention of fracture of the restoration (good mechanical strength, toughness and ductility). Composite resins have a matrix with nano-fillers, some examples of nanoparticles that can be used as fillers for resins, we can mention: hydroxyapatite (HA), silicon oxide (SiO2), zirconium oxide (ZrO2), carbon nanotubes and titanium oxide (TiO2) (LIMA *et al*., 2021; DUNCAN *et al*., 2022). Increasing certain nanomaterials can enhance the success of restorative procedures by promoting improvement in the physical, mechanical, and optical properties of resin materials; in addition, dental adhesives that have nanoparticles can improve penetration into the dentin tubules, increasing the contact area and, consequently, the mechanical strength of the restorations (ALHARBI *et al*., 2023).

Further research is needed to elucidate the innovations of adhesive systems, as well as their effectiveness and clinical applicability.

CONCLUSION

It is concluded that the appropriate selection of the adhesive system and the correct execution of the technique reduce the risk of postoperative sensitivity and increase the quality of adhesive strength in the long term. In addition, adhesives employing nanoparticles optimize the adhesive's penetration into the dental substrate, increasing the contact area and bond efficiency. The evolution of adhesives, as well as the use of nanotechnology and low molecular weight molecules, promotes the longevity of restorations. However, challenges remain, such as the complexity of the adhesion process, the need to remove the *smear layer*, and the effectiveness in demineralizing dentin. Nanotechnology has the potential to improve the properties of composites and adhesives, however, there are concerns regarding biocompatibility; Therefore, it is essential to continuously develop and improve adhesive systems for the challenges that still persist in dental practice, always aiming to improve the oral health of patients.

REFERENCES

1. Ahmed, M. (2020). Advances in adhesive systems in dentistry: A review. Journal of Adhesive Dentistry, 22(3), 245–259. https://doi.org/10.3290/j.jad.a54663.

2. Alam, M. K., et al. (2023). Advances in dental bonding agents: Historical perspectives and future directions. Materials Science and Engineering: C, 147, 112296. https://doi.org/10.1016/j.msec.2023.112296.

3. Al-Ani, A., et al. (2022). Adhesive dentistry: Recent developments and future perspectives. Journal of Dentistry, 119, 103967. https://doi.org/10.1016/j.jdent.2022.103967.

4. Alharbi, N. H., & Dhingra, K. (2023). Nanomaterials in dental composite resins: A comprehensive review. Materials, 16(5), 1985. https://doi.org/10.3390/ma16051985.

5. Ardila, C. M., et al. (2023). Nanoparticles in dental adhesive systems: A review of current applications and future prospects. Journal of Adhesive Dentistry, 2(1), 1–15. https://doi.org/10.3290/j.jad.a46985.

6. Arinelli, A. M. D., et al. (2016). Sistemas adesivos atuais: Revisão de literatura. Revista Brasileira de Odontologia, 3(3), 242–246. https://doi.org/10.1016/j.dental.02.009.

7. Boaru, M. O., et al. (2023). The influence of chlorhexidine gluconate dentine pre-treatment on adhesive interface and marginal sealing. Medicina, 59(2), 278.

8. Bourgi, R., et al. (2024). A literature review of adhesive systems in dentistry: Key components and their clinical applications. Applied Sciences, 14(18), 8111.

9. Breschi, L., et al. (2023). Bonding to dentin: A critical review of the literature. Journal of Dentistry, 126, 104289. https://doi.org/10.1016/j.jdent.2023.104289.

10. Buonocore, M. G. (1955). A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces. Journal of Dental Research, 34(6), 849–853. https://doi.org/10.1177/00220345550340060801.

11. Cardoso, P. M. D. F., et al. (2023). Effect of time and dental substrate on the bond strength of a universal adhesive system: In vitro study. Revista de Odontologia UNESP, 52, e20230005. https://doi.org/10.1590/1807-2577.00523.

12. Duncan, R., et al. (2022). Nanomedicine: A new era in the treatment of diseases. Journal of Drug Targeting, 30(4), 357–372. https://doi.org/10.1080/1061186X.2022.2071390.

13. Fehrenbach, J., et al. (2021). Is the presence of 10-MDP associated to higher bonding performance for self-etching adhesive systems? A meta-analysis of in vitro studies. Dental Materials, 37(10), 1463–1485.

14. Fernandes, L. R. (2021). Efeito remineralizante de sistemas adesivos experimentais com silicatos. App.uff.br. Disponível em: https://app.uff.br/riuff/handle/1/23590.

15. Froehlich, L., et al. (2021). Sistemas adesivos: Uma revisão da literatura. Research, Society and Development, 10(2), e36510212612. https://doi.org/10.33448/rsd-v10i2.12612.

16. Freire, M. V. D. S. (2019). Sistemas adesivos dentários contendo nanopartículas. Comum.rcaap.pt. Disponível em: https://comum.rcaap.pt/handle/10400.26/30705.

17. Hagger, O. (1951). Sevriton Cavity Seal: Desenvolvimento de adesivos dentários à base de resina acrílica. Journal of Dental Research, 30(2), 156–162.

18. Huang, Y., et al. (2022). Advances in adhesive dentistry: Nanotechnology applications in bonding agents. Materials Science and Engineering: C, 143, 112215. https://doi.org/10.1016/j.msec.2022.112215.

19. Kazak, M., et al. (2024). Comparative cell viability of dentin-bonding adhesive systems on human dental pulp stem cells: Time-dependent analysis. BMC Oral Health, 24(1), 663.

20. Kokol, P., et al. (2020). Buonocore research in adhesive dentistry: A remarkable sleeping paper. COLLNET Journal of Scientometrics and Information Management, 14(2), 211–217. https://doi.org/10.1080/09737766.2021.1906182.

21. Kubo, S., et al. (2021). Longevity of resin–dentin bonds in two-step and three-step etch-and-rinse adhesives: A systematic review and meta-analysis. Journal of Esthetic and Restorative Dentistry, 33(4), 619–629. https://doi.org/10.1111/jerd.12738.

22. Kulshrestha, A. (2023). Historical evolution of dentin bonding agents: A clinician's perspective. International Journal of Multidisciplinary Research and Analysis, 6(1). https://doi.org/10.2341/09-329-G.

23. Lima, A. M., et al. (2021). A nanotecnologia aplicada à Odontologia: Uma revisão da literatura. Odontologia: Pesquisa e Práticas Contemporâneas, 2(2), 59–75. https://doi.org/10.37885/211106725.

24. Liu, Y., et al. (2022). Advances in self-etch adhesives: A review of the literature. Frontiers in Dental Medicine, 2, 1–12. https://doi.org/10.3389/fdmed.2022.830994.

25. Lorenzetti, C. C., et al. (2019). Influência de tratamento dentinário com EDTA sobre a resistência de união de sistemas adesivos autocondicionantes. Revista de Odontologia da UNESP, 48. https://doi.org/10.1590/1807-2577.00719.

26. Martins, D. O., et al. (2014). Agentes antimicrobianos nos sistemas adesivos. Revista Brasileira de Odontologia, 71(2), 130–134. http://revodonto.bvsalud.org/scielo.php?script=sci_arttext&pid=S0034-72722014000200003.

27. Maletin, A., et al. (2023). Dental resin-based luting materials–review. Polymers, 15(20), 4156. https://doi.org/10.3390/polym15204156.

28. Medeiros, A. F., et al. (2019). Os efeitos das Metaloproteinases da matriz extracelular - MMPS e clorexidina no mecanismo de adesão dentária. Revista Salusvita (Online), 1127–1149.

29. Nakabayashi, N., Kojima, K., & Masuhara, E. (1982). The promotion of adhesion by the infiltration of monomers into tooth substrates. Journal of Biomedical Materials Research, 16(3), 265–273. https://doi.org/10.1002/jbm.820160307.

30. Oliveira, N. D., et al. (2010). Sistemas adesivos: Conceitos atuais e aplicações clínicas. Revista Dentística Online, 9(19), 1–9.

31. Pashley, D. H., et al. (2020). The durability of the resin–dentin bond: The effects of water and enzymes. Journal of Dental Research, 99(9), 1034–1041. https://doi.org/10.1177/0022034520939976.

32. Perdigão, J., & Swift, E. J. (2019). Fundamental concepts of enamel and dentin adhesion. Journal of Esthetic and Restorative Dentistry, 31(1), 51–68. https://doi.org/10.1111/jerd.12465.

33. Peumans, M., et al. (2021). Clinical effectiveness of contemporary adhesives: A systematic review of current clinical trials. Dental Materials, 37(4), e158–e176. https://doi.org/10.1016/j.dental.2020.12.021.

34. Pinheiro, R. F., et al. (1995). Desenvolvimento dos adesivos dentinários. Revista FOB. Disponível em: http://sddinforma.fob.usp.br/wp-content/uploads/sites/350/2010/07/1995artigo_10.pdf.

35. Rey, Y. C. D., et al. (2022). Phosphoric acid containing proanthocyanidin enhances bond stability of resin/dentin interface. Brazilian Dental Journal, 33(4), 62–70. https://doi.org/10.1590/0103-6440202203941.

36. Rodrigues, L. S., et al. (2021). Sistemas adesivos atuais e principais desafios na adesão: Revisão narrativa. Research, Society and Development, 10(10), e543101019206. https://doi.org/10.33448/rsd-v10i10.19206.

37. Sanches, K. L., et al. (2023). Factors affecting adhesive bonding to dentin and enamel: Clinical considerations and operator-related variables. Journal of Adhesive Dentistry, 25(1), 45–56. https://doi.org/10.3290/j.jad.a128753.

38. Santos, A. D., & Mendes, T. O. (2018). Sistemas adesivos resinosos: Uma revisão de literatura. Interciência, 20, 313–335. Disponível em: https://www.grupounibra.com/repositorio/ODONT/2023/sistemas-adesivos-uma-revisao-de-literatura.pdf.

39. Rosa, M. M., et al. (2023). Nanotechnology in medicine: Current trends and future perspectives. Frontiers in Bioengineering and Biotechnology, 11, 1245678. https://doi.org/10.3389/fbioe.2023.1245678.

40. Silva, P. A., et al. (2022). Adesão e técnicas de preparo dentinário em restaurações diretas: Uma revisão de literatura. Journal of Clinical Dentistry, 27(3), 150–160.

41. Souza, L. D., et al. (2018). Modificações nos protocolos de aplicação de sistemas adesivos: Revisão de literatura. Revista de Odontologia, 73(2), 173–177.

42. Takahashi, A., et al. (2021). Influence of MDP-based adhesives on the bonding durability to dentin and enamel in a self-etching approach. Journal of Adhesive Dentistry, 23(4), 337–345. https://doi.org/10.3290/j.jad.b1227253.

43. Tay, F. R., et al. (2022). Nanotechnology in dentistry: A review. Journal of Dental Research, 101(5), 514–524. https://doi.org/10.1177/00220345211061016.

44. Van Meerbeek, B., et al. (2011). State of the art of self-etch adhesives. Dental Materials, 27(1), 17–28. https://doi.org/10.1016/j.dental.2010.10.023.

45. Yoshihara, K., et al. (2018). Self-etch monomer technology: A review of current materials and future prospects. Journal of Adhesive Dentistry, 20(1), 7–26. https://doi.org/10.3290/j.jad.a39997.

46. Yoshihara, K., et al. (2021). Universal adhesives: A review of the literature. Journal of Adhesive Dentistry, 23(1), 43–59. https://doi.org/10.3290/j.jad.a44895.