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REVIEW

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Effectiveness of universal adhesives on primary tooth enamel: a literature review

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Abstract

Over recent years, minimally invasive techniques have been increasingly adopted in pediatric dentistry, leading to recommendations for materials that optimize clinical time and minimize handling errors. Consequently, the concept of a single-step adhesive—also known as a universal adhesive—has been widely described in permanent teeth and even in primary dentin as a reliable alternative capable of achieving predictable adhesive results, even without the application of phosphoric acid. However, there is no consensus regarding its use on the enamel of primary teeth. Therefore, the objective of the present literature review was to compile the available evidence to evaluate the effectiveness of universal adhesives. The literature search was conducted in PubMed, Scopus, ScienceDirect, LILACS, Wiley, and SciELO, including only articles published within the last ten years, in English and Spanish, that evaluated or compared at least one universal (single-bottle) adhesive. Both *in vitro* and clinical studies were considered. Thirteen studies met the eligibility criteria: 10 *in vitro* studies, 2 clinical trials, and 1 study with a mixed design that simultaneously conducted a clinical trial and an *in vitro* investigation. Most *in vitro* studies were performed on sound enamel, with the micro-shear bond strength (μSBS) test being the most frequently used. Overall, the findings suggested that selective enamel etching improved the bond strength of universal adhesives. In contrast, clinical trials evaluated only carious enamel and applied the United States Public Health Service (USPHS) criteria. The maximum follow-up period was 18 months, after which the results were heterogeneous. Although *in vitro* studies demonstrated increased effectiveness of universal adhesives with selective phosphoric acid etching, current clinical evidence remains insufficient to establish their efficacy in practice. Therefore, further well-designed, controlled clinical trials are warranted to clarify the clinical performance of these adhesives.

Keywords

Primary teeth; Dental enamel; Primary enamel; Universal adhesive

1. Introduction

One of the main challenges faced by pediatric dentists is achieving reliable adhesion, as microstructural and chemical differences exist between primary and permanent teeth [1, 2]. Therefore, understanding the characteristics of primary teeth is essential to elucidate the mechanisms of adhesion to the different dental substrates, namely dentin and enamel [3].

The enamel of primary teeth is thinner, has a lower mineral content, and presents a higher prism density [4]. In addition, it exhibits an aprismatic enamel layer with an approximate thickness ranging from 16 to 45 μm, which is considerably greater than that of permanent enamel, where it measures approximately 5 μm. This feature is particularly relevant, as it may hinder adhesive procedures in primary teeth [5].

Adhesive systems can be classified according to their etching strategy into two major groups: etch-and-rinse and self-etch systems [6]. The latter, also referred to as universal adhesives, multipurpose adhesives, or single-step adhesives [7, 8], differ from other adhesive systems mainly in that they contain an acidic primer and resin in a single bottle [9]. This provides the advantage of minimizing the handling of various materials, reducing chair time, and achieving shorter treatment time in pediatric patients. Furthermore, they can be used with different adhesive strategies and on a variety of substrates, providing high bond strength [10, 11].

Universal adhesives are self-etch systems to which functional phosphate and/or carboxylate monomers—such as 10-MDP (10-methacryloyloxydecyl dihydrogen phosphate)—have been added. This hydrophobic molecule enhances chemical bonding [12, 13]. These adhesives are capable of bonding to calcium in hydroxyapatite without causing extensive demineralization of enamel and dentin [14].

Based on their degree of acidity, these adhesives can be classified into four groups: ultra-mild (pH $\geq$2.5), mild (pH

≈ 2), moderate (pH 1–2), and strong (pH <1) [15]. This classification is crucial, as studies indicate that the effectiveness of these adhesives is directly related to their pH. Adhesive acidity allows penetration into the smear layer without neutralizing the functional monomer [16]. In dentin, mild pH adhesives demonstrate greater bond stability with resin, whereas in enamel, selective etching appears to enhance adhesion [17]. However, these findings have been widely reported for permanent teeth; in primary teeth, the available evidence remains contradictory [18]. Some studies report improved performance of universal adhesives on primary enamel when selective etching is applied [5, 19], while others indicate no significant differences [1]. This variability provides clinicians with multiple options when selecting the most appropriate application strategy, balancing clinical judgment with theoretical considerations [20].

Based on the foregoing, further compilation and analysis of up-to-date evidence are required to determine the effectiveness of universal adhesives on the enamel of primary teeth.

2. Material and methods

Two independent reviewers identified a total of 1137 articles and selected titles for abstract screening. After this initial process, 41 potentially relevant articles were obtained for full-text assessment; prior to this, 14 duplicates were removed, resulting in 27 articles that were read in their entirety. Subsequently, exclusion criteria were applied, and a total of 14 articles were excluded as follows: 1 article in Chinese language, 2 articles with no full-text available, 2 articles that did not use any universal adhesive, 2 articles that not used resin composite as restorative material (compomer), and 7 articles that did not follow manufacturer's instructions and had inadequate methodological quality. This resulted in a final inclusion of 13 articles. Any discrepancies were resolved through discussion between the reviewers, leading to a final consensus.

2.1 Inclusion criteria

- Full-text articles.
- Articles of *in vitro* studies and clinical trials from the last 10 years.
- Articles in English and Spanish.
- Studies that use or compare at least one universal adhesive (single step).
- Studies performed in primary enamel.

2.2 Exclusion criteria

- Articles in the format of literature review, case report, systematic reviews and meta-analysis.
- Incomplete or not available full text articles.
- Studies performed the analysis only on primary dentin.
- Studies that did not respect the protocol indicated by the manufacturer of the adhesive.

2.3 Search strategy

A literature search was conducted including only articles from 2016 to 2025, using the following platforms: PubMed, Scopus, ScienceDirect, LILACS, Wiley, and SciELO.

The following descriptors were used: MeSH (Medical Subject Headings) [(tooth, deciduous) AND (Dentin-Bonding Agents) AND (Dental Bonding) AND (Dental Enamel)]. Free-text search terms: Primary teeth OR primary dentition OR primary enamel OR deciduous enamel OR universal adhesive OR one-step universal adhesive AND bond strength.

3. Results

A total of 13 studies that met the eligibility criteria were included (Fig. 1), 10 *in vitro* studies, 2 clinical trials, and 1 study with a mixed design that simultaneously conducted a clinical trial and an *in vitro* investigation (Xu *et al.* [21], 2023).

3.1 Characteristics of *in vitro* studies

In vitro adhesive effectiveness was primarily evaluated using two approaches. The first examined the resistance to applied forces aimed at separating the resin–adhesive–enamel interface, while the second analyzed the sealing quality of the restorations (Table 1, Ref. [4, 5, 13, 19, 21–27]).

The most commonly used tests to evaluate the first aspect were: microshear bond strength (μSBS) [4, 22–24], shear bond strength (SBS) [19, 21, 25], microtensile bond strength [5] (μTBS) and microhardness [26]. While microleakage [26] and marginal integrity [13] tests were used to determine the second aspect.

The studies employed between 6 and 57 samples. The most frequently analyzed substrate was sound enamel, assessed in eight studies [5, 13, 19, 21, 23–25, 27]. Two studies included both sound and artificially eroded enamel [22, 26]. The erosion was produced by immersing the sample in Coca-Cola for one minute, four times per day, for five consecutive days, followed by abrasion with toothpaste using an electric toothbrush. Only one study evaluated both sound and demineralized enamel [4]. The storage time for the samples varied between 24 hours, 7 days, and 6 months, with distilled water being the primary storage medium [5, 19, 21, 23–25, 27]. Artificial saliva, Coca-Cola [22, 26], and tap water [13] were also used.

Most articles presented comparative analyses between universal adhesives and total-etch or self-etch adhesive systems. Scotchbond Universal was the most evaluated universal adhesive, while Adper Single Bond 2 and Clearfil SE Bond were the most used total-etch and self-etch adhesive systems, respectively. However, some studies only described the results for universal adhesives without comparison to other adhesive systems, with Scotchbond Universal and Clearfil Universal Bond Quick [5, 25] being the most used in these cases.

Most studies [4, 5, 19, 21, 23, 24, 27] reported that selective enamel etching improved the bond strength of the universal adhesive. In contrast, in the study conducted by Assunção *et al.* [22] 2020, Single Bond Universal results demonstrated superior performance than those obtained with Bond Force when applied in self-etch mode on eroded enamel.

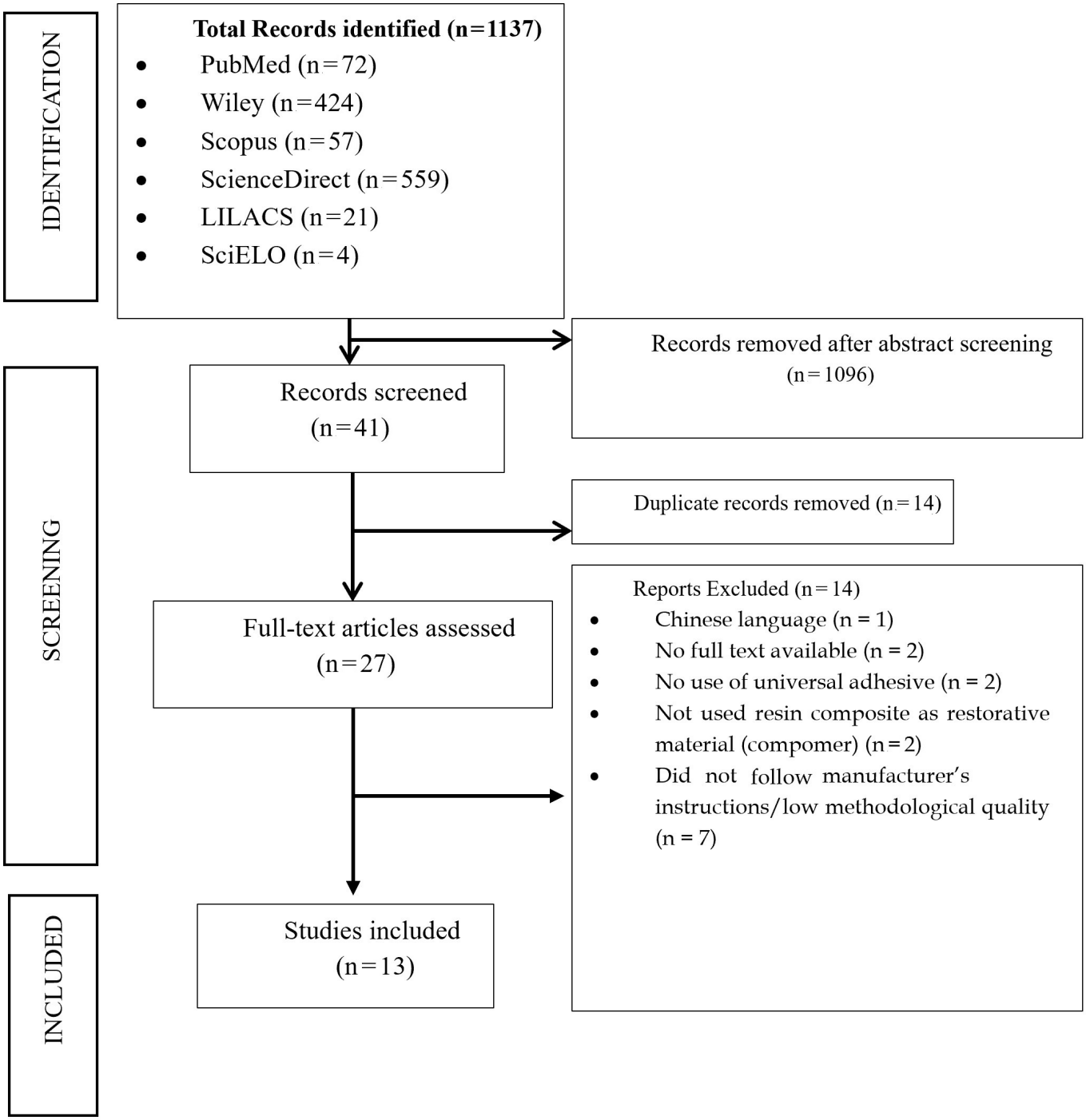

FIGURE 1. Flow chart of the literature retrieval method of this literature review.

3.2 Characteristics of clinical studies

The characteristics and results of the three selected studies are summarized in (Table 2, Ref. [1, 21, 28]). All evaluated only teeth with enamel caries.

The sample size ranged from 42 to 90. The caries removal technique involved selective removal using a curette [1] and complete removal [28]. To assess the effectiveness of the adhesives, the evaluation criteria established by the United States Public Health Service (USPHS) were used. These criteria evaluate restorations based on findings related to color, margin adaptation, anatomical form, surface roughness, marginal staining, occlusal contact, sensitivity, and secondary caries. The follow-up and control period ranged from 1 to 18 months.

Ortolani *et al.* [28] conducted a comparative analysis between a universal adhesive and a self-etch adhesive (Adper Easy One), while the other two studies [1, 21] compared the effectiveness of the universal adhesive employed with a self-etch technique and an etch-and-rinse technique. Xu *et al.* [21] reported that Scotchbond Universal obtained better results when selective enamel etching was applied, while Lenzi *et al.* [1] reported that Scotchbond Universal demonstrated better long-term results when used in self-etch mode.

TABLE 1. Characteristics of the *in vitro* studies included.

Author, Year, Country	Condition of enamel and number of teeth per group (n)	Universal adhesive system	Method of application of Universal adhesive	Other adhesive systems used	Storage time and fluid	Type of test	Results	Ref.
Antoniazzi, 2016, Brazil	Sound and demineralized (n = 6)	Scotchbond Universal (SBU)	Selfetch Etch-and-rinse	Clearfil SE bond (CSE)**	24 hours in water at 37 °C	Micro-Shear Bond Strength (μSBS)	SBU achieved better results than CSE in sound enamel applied in etch-and-rinse mode.	[4]
Alsaadawi, 2023, Saudi Arabia	Sound (n = 22)	Clearfil Universal Bond Quick (CUBQ), Scotchbond Universal (SBU)	Etch-and-rinse	-	AD	Shear Bond Strength (SBS)	CUBQ and SBU have excellent bonding properties to the primary enamel, and their bond strength is similar.	[25]
Assunção, 2018, Brazil	Sound and artificially eroded (n = 20)	Single Bond Universal	Self-etch	Adper Single Bond 2* Optibond FL* Bond Force**	Coca-Cola: 1 minute, 4 times a day, and artificial saliva at 25 °C	Microleakage and transverse microhardness	The different bonding systems tested showed no significant differences in adhesion or microleakage after erosion challenges.	[26]
Assunção, 2020, Brazil	Sound and artificially eroded (n = 12)	Single Bond Universal (SiBU)	Self-etch	Adper Single Bond 2* Optibond FL* Bond Force**	Coca-Cola: 1 minute, 4 times, followed by abrasion with toothpaste.	Micro-Shear Bond Strength (μSBS)	SiBU achieved better results on eroded enamel, but there was no significant difference compared to the other bonding systems used.	[22]
de Boer, 2023, Switzerland	Sound (n = 10)	Scotchbond Universal	Self-etch, Etch-and-rinse	-	AG (7 days)	Marginal integrity	SBU obtained similar results, irrespective of the application mode (self-etch or etch-and-rinse), however, reducing the adhesive rubbing time (from 20 to 10 seconds) reduced the marginal integrity of the restoration.	[13]
Hamdy, 2025, Germany	Sound Phase I: (n = 57); Phase II: (n = 44)	Scotchbond Universal, Clearfil Universal Bond Quick, iBond Universal Adhesive	Self-etch, Etch-and-rinse	-	AD	Microtensile Bond Strength (μTBS)	The different bonding systems tested showed better results when selective enamel etching was applied. Storage for 6 months reduced μTBS values in the selective etching group for 15 seconds.	[5]

TABLE 1. Continued.

Author, Year, Country	Condition of enamel and number of teeth per group (n)	Universal adhesive system	Method of application of Universal adhesive	Other adhesive systems used	Storage time and fluid	Type of test	Results	Ref.
Kim, 2021, South Korea	Sound (n = 12)	Scotchbond Universal, Clearfil S3 Bond Universal, Tetric N-Bond Universal, All Bond Universal	Etch-and-rinse	Adper Single Bond 2* Clearfil SE Bond**	AD	Shear Bond Strength (SBS)	Universal adhesives obtained lower SBS values in primary enamel when using the selective etching technique compared to Adper Single Bond 2ng in etch-and-rinse mode. (However, they did not use universal adhesive in self-etch mode).	[19]
Nozari, 2024, Iran	Sound (n = 10)	Gluma Bond Universal	Self-etch Etch-and-rinse	-	AD	Micro-Shear Bond Strength (μSBS)	Selective enamel etching improved the bond strength of the universal adhesive.	[23]
Omidi, 2022, Iran	Sound (n = 15)	G-Premio Bond	Self-etch, Etch-and-rinse	Adper Single Bond 2* Clearfil SE Bond** G-Bond**	AD	Microleakage	None of the adhesives prevented total microleakage, but G-Premio Bond obtained the best result with selective enamel etching.	[27]
Tichy, 2023, Czech Republic	Sound (n = 10)	Clearfil Universal Bond Quick, G-Premio Bond	Self-etch	Clearfil SE Bond 2* Clearfil SE Bond 2** G2 Bond Universal* G2 Bond Universal**	AD	Micro-Shear Bond Strength (μSBS)	Two-step self-etch adhesives and universal adhesives obtained similar values at 24 hours; however, after thermocycling, the universal adhesive group obtained the worst results, suggesting that universal adhesives need selective enamel etching.	[24]
Xu, 2023, China	Sound (n = 10)	Single Bond Universal (SBU)	Self-etch, Etch-and-rinse	Adper Single Bond 2*	AD	Shear Bond Strength (SBS) and Microleakage	Etch-and-rinse SBU presented the highest SBS, with the worst results obtained in self-etch mode. Etch-and-rinse SBU did not present marginal leakage, or there was leakage without exceeding 1/3 of the cavity; the greatest leakage was observed in the self-etch SBU group.	[21]

**Etch-and-rinse adhesive; **Self-etch adhesive. AD: water distilled at 37 °C for 24 hours; AG: tap water at 37 °C.*

TABLE 2. Characteristics of the clinical studies included.

Author, Year, Country	Condition of enamel and number of teeth per group (n)	Universal adhesive system	Method of application	Other adhesive systems used	Follow-up time (recall)	Evaluation criteria	Results	Ref.
Lenzi, 2017, Brazil	Carious (n = 90)	Scotchbond Universal (SBU)	Selective removal of carious tissue until curette resistance is achieved. Self-etch, Etch-and-rinse	-	1, 6, 12, and 18 mon	United States Public Health Service (USPHS) Criteria	SBU in self-etch mode achieved better long-term clinical results compared to SBU in etch-and-rinse mode; however, both strategies perform well clinically after selective caries removal.	[1]
Ortolani, 2016, Argentina	Carious AEO (n = 66); SBU (n = 81)	Single Bond Universal (SBU)	Complete removal of caries. Etch-and-rinse	Adper Easy One (AEO)	6–7 mon, 10–12 mon	Modified Ryge criteria	SBU had a lower failure rate (6–9%) than AEO (7–13%), but this difference is not significant. It can therefore be stated that both achieved similar and acceptable results.	[28]
Xu, 2023, China	Carious (n = 42)	Single Bond Universal (SBU)	Teeth were cleaned and dried. Self-etch, etch-and-rinse	-	7 d, 6, 12, and 18 mon	United States Public Health Service (USPHS) Criteria	The use of SBU in self-etch mode showed greater loss of restorations and more secondary caries at 12–18 months, compared to the etch-and-rinse group.	[21]

U.S. Public Health Service criteria: evaluates color, marginal adaptation, anatomical form, surface roughness, margin staining, occlusal contact, sensitivity, and secondary caries. Modified Ryge criteria: evaluates color, margin adaptation, anatomical form, surface roughness, marginal staining, restoration staining, occlusal contact, sensitivity, secondary caries, and gloss/luster.

4. Discussion

The search for a practical adhesive system that minimizes errors during restorative procedures has led to the adoption and recommended use of universal adhesives [29]. They have been extensively evaluated in the context of permanent teeth [30] and even primary dentin [31]. However, there remains a lack of consensus regarding their application to primary enamel [6]. Thus, this literature review aims to describe the effectiveness of universal adhesives on primary tooth enamel based on evidence from *in vitro* and clinical studies.

One of the main limitations encountered in conducting this study was the limited number of investigations addressing this topic. Furthermore, the few studies identified, whether clinical or *in vitro*, were carried out under diverse conditions, which hindered the critical interpretation of the information and the adequate explanation of the findings. In this regard, particularly in clinical trials, it is necessary to standardize procedures and data collection instruments.

The analysis of the *in vitro* studies included in this review shows a direct relationship between selective enamel etching with phosphoric acid and the increased bond strength of universal adhesives. This relationship has been demonstrated through various testing methodologies, with the micro-shear bond strength (μSBS) [32] test emerging as the most used and recommended as it provides more accurate results. Thus, after comparing Clearfil SE Bond with Scotchbond Universal, Antoniazzi *et al.* [4] concluded that Scotchbond Universal demonstrated better results when applied to sound enamel in etch-and-rinse mode. They also observed that, irrespective of the etching mode, the performance of the two adhesives was affected when applied to demineralized enamel. For this reason, it is important to highlight that, in addition to the histological differences between permanent enamel and primary enamel, there are other differences between sound and demineralized primary enamel. The latter exhibits a reduction in the individual crystal content, resulting in enlargement of the intercrystalline spaces and increased tissue porosity [33]. Thus, complete removal of demineralized enamel is recommended for a predictable adhesive result, particularly given that selective removal techniques are widely used in pediatric dentistry, which may leave undetectable demineralized enamel, on which a universal adhesive performs differently [34].

Recent studies by Hamdy *et al.* [5] and Nozari *et al.* [23] evaluated the bond strength of different brands of universal adhesives applying different adhesive strategies and found that previous selective etching is key to achieving adequate adhesion to primary enamel, irrespective of the pH level of the adhesive.

Conversely, a study on permanent teeth conducted by T Suzuki *et al.* [35] indicated that the application of the All Bond Universal self-etching strategy (pH = 3.2) resulted in inferior adhesive values compared to more acidic adhesives such as Scotchbond Universal (pH = 2.7) and Prime&Bond Elect Universal (pH = 2.5). This suggests that manufacturers use different components (monomers such as 10 MDP, solvents such as alcohol, acetone, or water, *etc.*) [14] and results in variations in the acidity of the adhesive, which in turn affects their performance in self-etching applications [17]. This finding aligns with those of this review. Tichy *et al.* [24] compared in their study two universal adhesives with different pH levels: G-Premio Bond (pH = 1.5) and Clearfil Universal Bond Quick (pH = 2.3), and reported greater enamel surface roughness with the use of the more acidic adhesive.

Despite the encouraging results associated with universal adhesives in self-etch mode [25], these adhesives are not yet capable of producing the enamel etching patterns achieved with phosphoric acid. These patterns are deemed necessary for acceptable bond strength values in primary enamel [36], since adhesion to this tissue primarily relies on the micromechanical interlocking between the adhesive and the microporosities of the enamel [3].

The findings from the microleakage and marginal integrity tests [13, 21, 27], concluded that acid etching improved the sealing quality of the enamel-resin interface when the universal adhesive was compared with self-etch and etch-and-rinse adhesive systems, such as Clearfil SE Bond or Adper Single Bond 2, respectively. These results further support the need to use phosphoric acid prior to the application of the universal adhesive.

Various systematic reviews and meta-analyses analyzing only *in vitro* studies reveal contradictions with our findings. For instance, Fröhlich *et al.* [6] concluded that there remains uncertainty whether selective acid etching of primary enamel is necessary when universal adhesive systems are used. Similarly, da Silva *et al.* [3] indicated that a mild 10-MDP-based universal adhesive system can serve as an alternative to the traditional etch-and-rinse or self-etch systems for restorations of primary teeth. These affirmations should be interpreted carefully, as the scientific evidence available until 2021, when both studies were published, was limited and only 1–2 studies on primary enamel were analyzed in both cases.

The analysis of clinical evidence is fundamental, as *in vitro* studies, while providing valuable information, may not yield results that can be directly extrapolated for clinical assessment, even when efforts have been made to replicate environments or conditions similar to those of the oral cavity [22, 26]. It is observed that all studies included in this review employed Scotchbond Universal, probably due to its common use in *in vitro* studies. One study, after 18 months of observation in self-etch mode [1], reported a trend toward better clinical performance. This finding aligns with the recent results of Perdigão *et al.* [37], who reported a 100% success rate in Class I and Class II restorations one year after placement using Scotchbond Universal in self-etch mode, in a study on permanent teeth. However, a more recent study [21] with a similar observation period reported better performance of restorations in this group when phosphoric acid was applied prior to adhesive application. This was evidenced by a lower percentage of complete or partial loss, improved margin adaptation, and reduced discoloration compared to those that were applied in self-etch mode.

Both studies applied the same USPHS evaluation criteria [38]. This finding may be attributed to the increased etching time, from 15 to 30 seconds, respectively, and to the fact that the most recent study was conducted only on Class II cavities. It is important to highlight that the latter study lacked

a detailed description of the caries removal procedure and the adhesion protocol; therefore, its conclusions should be interpreted carefully.

In relation to these findings, a 5-year clinical evaluation [39] of non-carious cervical lesions in permanent teeth concluded that selective enamel etching is fundamental for the survival of this type of restorations. Similarly, a clinical study included in this review, conducted by Ortolani *et al.* [28], comparing Scotchbond Universal with a single-step self-etch adhesive (Adper Easy One), both applied using the etch-and-rinse technique, concluded that the universal adhesive demonstrated better performance, although it was not significant.

One of the most extensive clinical trial on primary teeth was conducted by Pitchika *et al.* [18], who followed the clinical performance of self-etch adhesives and etch-and-rinse adhesives for up to seven years. They found that self-etch adhesive restorations were more likely to survive longer. Although the study did not include universal adhesives, it establishes a clinical precedent for the use of simplified adhesive methods. Due to the limited number of available studies, it is important to conduct further clinical trials evaluating the use of universal adhesives, including a larger number of participants [1] and comparing their outcomes with those of two- or three-step adhesive systems. The long-term success of resin restorations begins with an appropriate adhesive procedure; however, it should also be considered that, in line with the needs of pediatric dentists, it is essential to establish a validated simplified protocol that meets the highest quality standards and guides the appropriate selection of restorative materials.

Due to the limited clinical evidence obtained, it is not possible to determine with certainty how universal adhesives perform on primary tooth enamel, especially for the absence of long-term studies and standardized clinical evaluation criteria.

5. Conclusions

Universal adhesives demonstrate effectiveness *in vitro* performance when compared with self-etch or etch-and-rinse adhesive systems.

The selective etching strategy with phosphoric acid significantly improved the effectiveness of universal adhesives on primary tooth enamel in most *in vitro* studies.

Due to the lack of clinical study findings, it remains difficult to establish with certainty the clinical effectiveness of universal adhesives on primary tooth enamel.

AVAILABILITY OF DATA AND MATERIALS

Not applicable.

AUTHOR CONTRIBUTIONS

DISP—designed the research study; performed the research; wrote the manuscript. DISP, KJCC—analyzed the data. Both authors contributed to editorial changes in the manuscript. Both authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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