



## Review Article

# Status of decontamination methods after using dentin adhesion inhibitors on indirect restorations: An integrative review of 19 publications



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## ABSTRACT

The purpose of this review was to assess the literature regarding the decontamination of resin cement before the luting procedure in order to provide clinicians with a comparative overview of decontamination effects. A total of 19 articles were selected for inclusion in this review. The results indicated that bonding effectiveness is reduced due to residual adhesion inhibitors such as saliva, blood, hemostatic agents, and temporary/provisional cement. Self-etching and self-adhesive systems tend to be more negatively affected by adhesion inhibitors than do etch and rinse systems. Cleaning with an ultrasonic scaler or rotating brush have demonstrated conflicting effects in several studies. Some studies have reported that phosphoric acid has negative effects and recommend mild acid for decontamination. The application of phosphoric acid followed by sodium hypochlorite has been shown to help avoid negative effects. Alumina blasting has been investigated as a mechanical cleaning method in a relatively large number of experiments, most of which have confirmed its effectiveness. An intraoral cleaner containing functional monomers that has become commercially available in recent years is a promising method in clinical practice because it can easily and effectively remove temporary adhesive material. In addition, adhesion inhibitors can be easily removed from resin-coated dentin surfaces.

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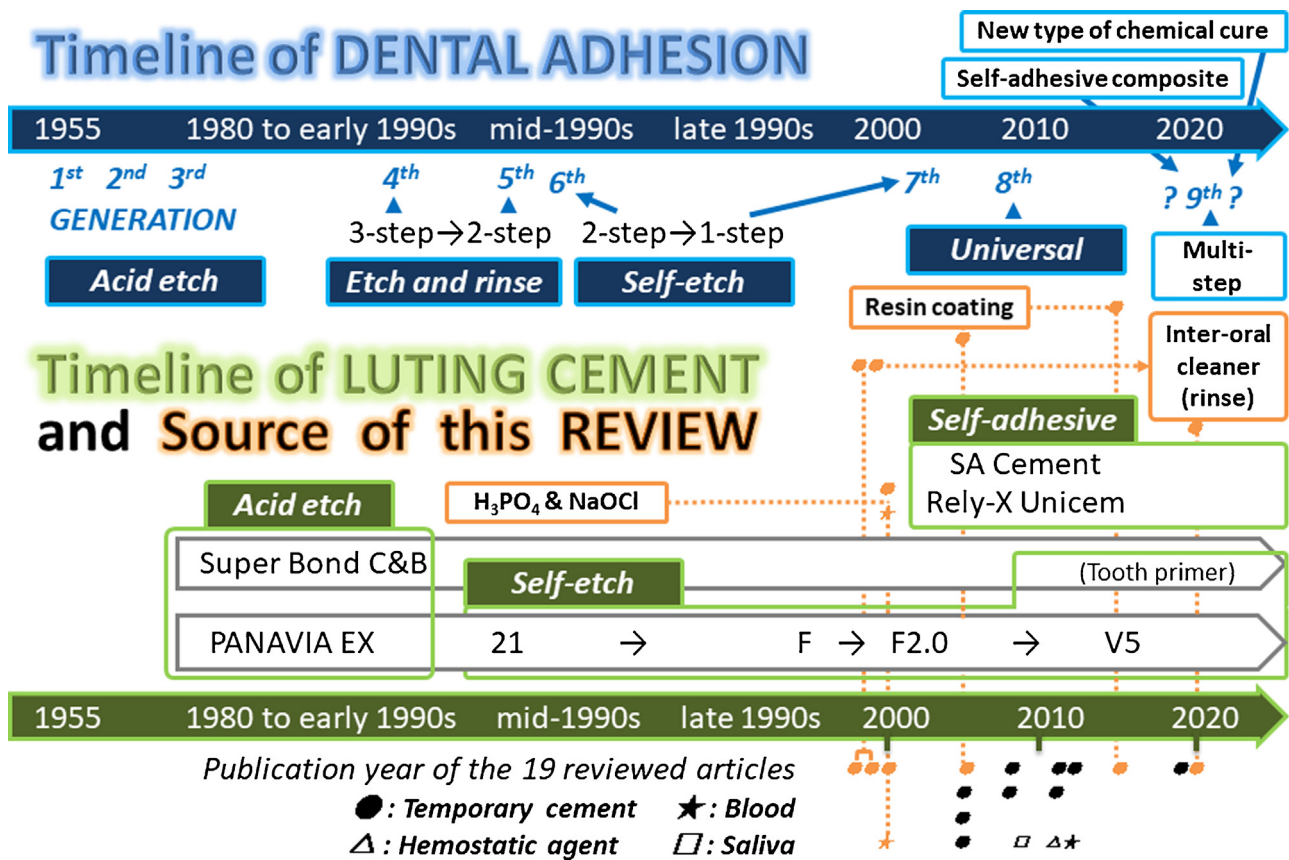
## 1. Introduction

Adhesive technology has evolved rapidly since it was introduced in 1955 (Fig. 1, upper row) [1]. After achieving clinically promising bonding to dentin by a three-step etch and rinse procedure in the early 1990s, the demand for simpler, more user-friendly, and less technique-sensitive adhesives has remained high, prompting manufacturers to develop new adhesives at a rapid pace [1–3]. The challenge for dental adhesives led to the successful development of one-step one-bottle adhesives (so-called 7th generation adhesives) in the early 2000s. The demand for new dental adhesives has con-

tinued with the recent launch of (1) new chemical cure adhesives that do not require light curing time, (2) self-adhesive resin composite (i.e., 0-step adhesives), and (3) multi-step adhesives with a hydrophobic bonding agent, which can be categorized as 9th generation adhesives. Basically, the bonding effectiveness of 7th and 8th generation adhesives (one-step one-bottle adhesives) is lower than that of 6th generation adhesives (two-step self-etch adhesives) [4]. Also, self-adhesive resin composite is characterized as having limited interaction with enamel and dentin [5,6]. Similar to bonding agents, the demand for ease of use affected the development of luting resin cement, and as a result, self-adhesive resin cement is now widely used in the clinical setting (Fig. 1, middle row). In addition, the bonding effectiveness of simplified luting cement is lower than that of conventional resin cement, similar to bonding agents [7].

Bonding agents for direct composite restoration and luting cement for indirect restoration have both been evaluated, mainly

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**Fig. 1.** Schematic illustration of the timeline of dental adhesion/luting cement and sources used in this review. The upper part of the figure shows a timeline that provides a historical perspective regarding the development of dental adhesive technology, mainly for direct restoration [1]. The active ingredient in **first-generation adhesives** was a functional monomer, glycerophosphate dimethacrylate, which improved adhesion to dentin through the use of a hybrid layer. This hybrid layer is formed at the dentin surface by (partial/full) demineralization followed by infiltration of monomers and their subsequent polymerization. The disadvantages of these first-generation adhesives were their instability and low bond strength. Consequently, **second-generation adhesives** were developed to interact with either organic or inorganic components. In contrast to the first-generation adhesives, second-generation adhesives actually bonded to the smear layer; however, these adhesives were very weakly attached to the underlying dentin. Subsequently, the Japanese concept of etching dentin to remove the smear layer formed the basis for **third-generation adhesives**. These developments finally led to **fourth-generation adhesives**, in which a conditioner and a primer were used separately before the application of adhesive resin for bonding. Fourth-generation adhesives were considered the first adhesive class that could provide favorable clinical outcomes. Thus, to achieve good clinical effectiveness, dentin adhesive technology evolved from one-step/component to three-step adhesives. Next, research and development focused on the next phase, simplification, to reduce the number of application steps. This led to **fifth-generation adhesives** (i.e., 2-step etch and rinse, which combined the primer and bonding agent in a one-bottle adhesive) and **sixth-generation adhesives** (i.e., 2-step self-etch, which involved an acidic self-etch primer that combined the acidic etchant with a primer, followed by the application of bonding). The middle part of the figure shows the timeline for luting cement. Similar to direct restoration, it starts with the acid etch system and develops into the self-etch system. In addition, the self-adhesive system, which does not require adhesives, is also widely used. The lower part of the figure shows a breakdown of the 19 articles reviewed in this study (see Supplementary Table for more details). “H<sub>3</sub>PO<sub>4</sub> & NaOCl”, “Resin coating”, and “Inter-oral cleaner” are shown in regard to decontamination.

in laboratory tests such as bond strength tests and microscopic observations [8]. However, in contrast to the laboratory situation, some adhesion inhibitors exist inside the patient’s mouth. One such contaminant is saliva, the effect of which has been investigated in numerous studies. The influence of salivary contamination on the bond quality of adhesives used in restorative materials was reviewed and critically analyzed by Nair et al. [9] through a comparison of different adhesive materials. They concluded that salivary contamination was a possible reason for the poor bond quality of adhesive systems during restorative procedures and thus, to provide successful treatment, proper care should be taken to ensure that the operating area is free from contamination. In this way, a number of different dentin bond strengths have been described in various studies using direct composite restorations. Nevertheless, limited information is available on dentin bonding during indirect restorations, especially information about effectively removing the inhibitor. Compared with direct restoration, indirect restoration is greatly affected by adhesion inhibitors. Nevertheless, in clinical studies, indirect restorations have exhibited a significantly

lower mean annual failure rate compared with direct techniques [10].

Understanding the effect of decontamination due to potential vulnerabilities after contamination in the luting area could help produce better clinical outcomes. Therefore, to provide a comparative overview of the effects of decontamination in indirect restoration, this study aimed to review the literature regarding decontamination before a luting procedure involving resin cements.

## 2. Subjects and methods

We performed an electronic search of the literature via the PubMed database (Table 1). The inclusion criteria were peer-reviewed articles published in English between January 1947 and March 28, 2021. We searched for additional relevant literature based on the reference citations in the papers retrieved from the initial literature search. We excluded studies that did not focus on indirect restoration or provide data on bond strength. We also

**Table 1**  
The search strategy used in this review.

	Terms and formulas	Number of manuscripts
#1	(dental bonding [MeSH Major Topic]) AND (resin cements [MeSH Major Topic]) AND (dentin [MeSH Terms])	1121
#2	#1 AND (saliva [MeSH Terms])	10
#3	#1 AND (blood [MeSH Terms])	7
#4	#1 AND (hemostatics [MeSH Terms])	3
#5	#1 AND (temporary [All Fields])	21
#6	#1 AND (provisional [All Fields])	10
#7	#1 AND (contamination [All Fields])	31
#8	#2 or #3 or #4 or #5 or #6 or #7	52
#9	#8 filters: English, humans	52

MeSH: Medical Subject Headings. Data acquired on January 26, 2021 (PubMed).

excluded papers that did not describe decontamination methods, even if contamination was a topic of the research. We carefully appraised the titles and abstracts of all papers to remove those that were outside the scope of this review. In the event that we could not determine the focus of the paper accurately from the title or abstract, we examined the full-text article. As a result, we recorded the following variables (information) from the included studies: Manuscript information (authors, year, journal), experimental condition (bonding test methods, aging step, additional test, contamination procedure, resin-coating method, luting cement, cleaning methods), and obtained information (test results, conclusion of the research, notes).

Additionally, we performed a search on Web of Science to identify the number of citations of all articles from 1945 through March 31, 2021.

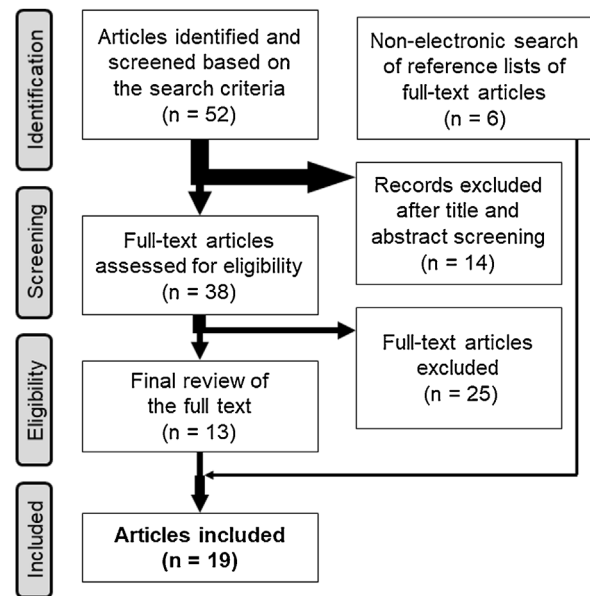
### 3. Results and discussion

#### 3.1. Overview

A total of 52 papers were identified (from 1990 to 2020), 39 of which were excluded after a review (about adhesives, not using resin cement: 20 papers; not including bond strength test: 4 papers; review without any data: 3 papers; no examination of decontamination or simple explanation of the contamination effects of decreased bond strength: 10 papers; and using glass ionomer cement: 2 papers). We also included six papers found in a manual search, resulting in a total of 19 articles for inclusion in this review [11–30] (Fig. 2).

These 19 articles were published between 1998 and 2020, most before 2012 (Fig. 1, lower row and Appendix A (Table)). Only four studies (T#1, 6, 7, and H#1) described self-adhesive luting cement, two of which from the same journal had a higher number of citations compared with that of other articles. As for the research methods, the majority of papers ( $n = 10$ ) used the shear bond strength test because of the use of luting cement, followed by the tensile test ( $n = 4$ ), micro-tensile test ( $n = 4$ ), and micro-shear test ( $n = 1$ ), whereas aging procedures were carried out in only four studies. Morphological observations under scanning electron microscope were carried out in 17 of the studies, and elemental analysis by energy dispersive X-ray spectroscopy (EDS) was performed in five. As for the dentin substrate, human teeth were prepared in 12 studies and bovine teeth in seven, among which, six were conducted in Japan.

Regarding the kind of contamination, temporary/provisional cement was examined as the major source of contamination in 15 papers, followed by blood in two and hemostatic agents and saliva in one each. From the next section, the removal method and considerations are described for each of these contaminations.



**Fig. 2.** Flow diagram outlining the identification of articles and screening process adapted in the present review.

#### 3.2. Saliva contamination

At around the same time as the start of adhesive dentistry, saliva has been considered an adhesion inhibitor on the surface to be restored (Fig. 1). In 1971, it was reported that acid-conditioned tooth surfaces absorb salivary constituents and decrease the surface energy, and are therefore detrimental to bonding [31]. In a recent review, salivary contamination occurring during restorative procedures at either one or multiple stages of direct restoration had an adverse effect on adhesives, but two-step etch and rinse adhesives were relatively less vulnerable to salivary contamination compared with the other types of adhesives examined [9]. In self-etching systems, saliva contamination has been shown to change the pH value of dentin surfaces and decrease the bond strength; however, re-priming with a self-etching primer system was adequate to restore the bond strength [32].

In terms of indirect restoration, Chung et al. [29] (S#1) investigated the effects of saliva contamination on the bond strength of two types of resin luting cement to dentin, as well as the effects of different decontamination methods. They found that decontamination by water-rinsing and primer re-application after rinsing improved the bond strength of a self-etching system. For the etch and rinse system, decontamination by rinsing with water was the most effective for restoring bond strength. Interestingly, the action of re-etching the dentin was detrimental to the adhesive surface structure. As saliva contamination after preparation cannot be avoided in indirect restorations, it is not a concern when using indirect compared with direct restorations.

#### 3.3. Blood contamination

Blood contamination has been reported to impair the adhesion between dentin and resin [30,33]. The protein and lipid derived from blood has been shown to remain on the dentin surface, even after rinsing away the blood contaminants with water for 15 s, according to the leucomalachite green test and observation by confocal laser scanning microscopy [34]. It has also been reported that collagen network exposure by citric acid solution can lead to a more stable fibrin network and blood cell attachment to the dentin surface [35].

Takefu et al. [26] (B#1) reported that the leakage value and micro-tensile bond strength were restored to an uncontaminated group after re-treating the surface with 10-3 solution (10% citric acid [pH 0.86] and 3% ferric chloride) and rinsing with water; however, re-etching by phosphoric acid after saliva contamination reduced the bond strength, as mentioned in a previous section (3.2. Saliva contamination). These inconsistent results were considered the result of the different acids used. Citric acid, which is known to have protein removal ability and anticoagulant action because of its calcium chelating properties, is commonly used in clinical medicine for blood sampling and in central dialysis fluid delivery systems for hemodialysis (the so-called heat citric acid disinfection method) [36]. In addition, compared with the uncontaminated group, no significant difference was seen in the leakage value and bond strength when blood contamination occurred before surface treatment.

Kaneshima et al. [27] (B#2) attempted to determine in which step of adherent surface treatments blood contamination affects the bond strength between a self-etching adhesive resin with or without phosphoric acid and sodium hypochlorite treatment. They concluded that the bond strength was restored at any stage of the adhesive process by washing away the blood, air-drying, and applying a self-etching primer. Therefore, the decontamination procedures for saliva and blood can be considered the same as that for self-etch resin cement. Moreover, it can be inferred that the cause of the lack of research on these decontamination procedures is the weak effects of saliva and blood as adhesion inhibitors.

### 3.4. Hemostatic agent contamination

Hemostatic agents are acidic solutions that have been used for many years to control bleeding in clinical dentistry, the main active ingredients of which are aluminum chloride and ferric sulfate. The pH values of hemostatic agents range from 1.1 to 3.0, and are thus in the same range as those of self-etching primers [3,37]. Hemostatic agents can be contaminants for adhesion and may cause the etching effect to the dentin surface because of acidity.

Chaiyabutr and Kois [28] (H#1) reported that to restore the bond strength to pre-contamination levels when using a self-adhesive resin cement after hemostatic contamination with 25% aluminum chloride or 13% ferric sulfate, the cleansing protocol should include particle abrasion with low-pressure aluminum oxide or phosphoric acid etching. In addition, the mean bond strengths of the specimens in the acid etch and particle abrasion groups were not significantly different from those of specimens in the control group; by contrast, the lowest mean bond strength was seen in the group that underwent water rinsing only. Similar to the clinical setting, these effects were evaluated after dentin contamination with blood followed by application of the hemostatic agent. Therefore, contamination should not be considered to be a result of hemostatic contamination only, but rather, as a consequence of both.

Nevertheless, dentists want to start adhesion procedures quickly after using a hemostatic agent because any cleaning method may cause bleeding again. Therefore, “pretreatment” to reduce the negative effects of hemostatic agents are appreciated by clinicians (the details will be described later).

### 3.5. Temporary/provisional cement contamination

Temporary/provisional restoration and cementation on dentin surfaces are important procedures for restoration or prosthesis retention to avoid pain and infection and restore function and esthetics [38]. However, if the materials used in the preliminary stage remain on the dental surface, they may be adhesive-inhibiting factors during final cementation. Several studies have reported

that the use of temporary cement negatively affects the bonding strength of resin-based luting agents to dentin [38,39].

Among temporary/provisional cements, eugenol-based temporary cements are basically not recommended for use together with resin-based luting agents because eugenol is known to inhibit the radical polymerization reaction [40]. Munirathinam et al. [14] (T#4) reported that in practice, eugenol-containing provisional restorations impair the properties of resin cement, and suggested that this was because of an inhibitory effect on resin polymerization. Other studies, such as those by Fonseca [19] (T#9) and Latta [20] (T#10), have reported finding no adverse relationships between eugenol-containing provisional restorations and the bond strength of resin cements, which suggests that the effects of temporary/provisional restorations on resin-cement adhesion cannot be generalized; rather, any such effects appear to be specific to the cement and adhesive cement system. Therefore, in this review, temporary/provisional cements are not classified into eugenol and non-eugenol, but rather, considered as factors that remain on the surface and inhibit adhesion; the cleaning and decontamination methods are described below.

#### 3.5.1. Mechanical cleaning 1: sonic scaling, rotary instruments, and rotational brushes

The mechanical removal of temporary cements is not effective when using only excavators or other hand instruments [38]. Macroscopically, dentin surfaces may appear clean, but microscopically, temporary cement residues that reduce the bonding of resin cements can be observed [38]. Kanakuri et al. [22] (T#12) reported that air scaler cleaning, which is often used in the clinical setting, is a significantly less effective cleaning method compared with not only rotational brushes, but also sonic toothbrushes.

Investigators have attained variable results regarding the use of rotary instruments without cleaner, with some supportive of their use for cleaning provisional cement on dentin [22] and others not [15,18]. Kanakuri et al. [22] (T#12) recommended the use of rotational brushes with water coolant compared with other methods (e.g., non-fluoridated flour of pumice, air-scaler, sonic toothbrush) for cases involving temporary polycarboxylate cement.

In clinical dentistry, pumice flour has been used for many years as an abrasive or polishing agent to clean teeth and remove plaque and debris from the area to be bonded. However, as reported by Santos et al. [16] (T#6) and Fonseca et al. [19] (T#9), pumice slurry cleaning using a rotary instrument resulted in a low bond strength value and was not significantly different from controls (hand scaler or excavator).

#### 3.5.2. Chemical cleaning 1: ethylenediaminetetraacetic acid (EDTA) and polyacrylic acid

Munirathinam et al. [14] (T#4) evaluated temporary cement-contaminated dentin and resin cement bonding using a two-step etch and rinse adhesive, and found that 17% EDTA cleaning resulted in better shear bond strength values compared with pumice flour and ultrasonic scaler cleaning with 0.2% chlorhexidine gluconate. Thus, EDTA is more efficient for removing the remnants of provisional cement and the smear layer covering the dentinal tubules.

Santos et al. [16] (T#6) investigated whether a weak acid (40% polyacrylic acid) could enhance bonding by providing further demineralization and found, consistent with data from other studies [41,42], that it did not improve shear bond strength compared with a control group. Polyacrylic acid has been shown to increase surface roughness and expose the dentinal tubules [42], but with only limited diffusion of the self-adhesive resin cement.



### 3.5.3. Chemical cleaning 2: phosphoric acid and phosphoric acid and sodium hypochlorite (NaOCl)

Phosphoric acid is often used for surface cleaning in the clinical setting; however, few studies have evaluated its effectiveness. Watanabe et al. [23] (T#13) reported that 38% phosphoric acid etching for decontamination of temporary cement before the use of self-etching primer was ineffective. As mentioned earlier, over-etching should be avoided before performing any adhesion procedures.

The formation of a hybrid layer consisting of resin and collagen is considered a major advance in adhesive dentistry and has greatly contributed to greater bond strength between dentin and resin composite/cement (Fig. 1). However, if any remaining etched dentin (i.e., collagen) is not penetrated by the resin, the non-penetrated zone should be considered a weak point under the resin cement/composite. The use of NaOCl for deproteination of the etched zone has been shown to achieve beneficial results [43–45]; the effectiveness of this method has also been confirmed for later-generation adhesive systems [11,46–49] (Fig. 1). Watanabe [23] (T#13) reported that in terms of bond strength, this treatment was more effective than etching with phosphoric acid alone for temporary cement-contaminated dentin, and that no temporary cement remained after this treatment as revealed by EDS analysis. Tajiri-Yamada [11] (T#1) also reported this result in regard to self-adhesive cement. Although phosphoric acid and NaOCl treatment is effective for chemical cleaning, it should be noted that NaOCl inhibits polymerization, especially when using tri-*n*-butyl borane as a catalyst [48,49].

### 3.5.4. Mechanical cleaning 2: blasting

Alumina blasting is a relatively old technique that is still widely used by prosthodontists and dental technicians. Yamashita and Yamami [50] first used alumina with a particle size of 50  $\mu\text{m}$  for metal-resin adhesion to clean bonding surfaces, create mechanical retention, and increase the bonding surface area, resulting in higher bond strengths. Nowadays, this method is the gold standard for surface treatment of not only metal, but also zirconia [51,52] and computer-aided design/computer-aided manufacturing (CAD/CAM) indirect resin composite bonding [53,54]. To remove temporary cement from dentin, Fonseca et al. [19] (T#9) evaluated the cleaning effectiveness of alumina blasting compared with pumice-water slurry and a hand scaler before the use of an etch and rinse system in 2005. Chaiyabutr and Kois [17] (T#7, 2008) and Santos et al. [16] (T#6, 2011) also examined the decontamination effectiveness of alumina blasting before the use of self-adhesive system decontamination. These studies all clearly reported that alumina blasting was a more effective method for decontamination compared with hand instruments (excavators or scalers) and pumice.

Alumina with a particle size other than 50  $\mu\text{m}$  and other kinds of blasting material have also been examined. Chaiyabutr and Kois [17] (T#7) investigated the decontamination ability of alumina (particle size: 27  $\mu\text{m}$  and 50  $\mu\text{m}$ ) and did not find significant differences in bond strength. Nonetheless, they speculated that the bond strength was increased as a result of using low-pressure and small particle abrasion-treated dentin as a mechanical cleansing protocol before definitive cementation. Januário et al. [12] (T#2) evaluated the effects of a removal method for temporary cement residue using pumice paste, air abrasion with alumina, sodium bicarbonate spray, and glycine powder, and declared that only alumina abrasion (particle size: 50  $\mu\text{m}$ ) had a higher range of dentin bond strength.

### 3.5.5. Pretreatment 1: resin-coating

Resin-coating not only provides greater pulp protection and bond strength, but also reduces pain during the insertion and removal of a provisional restoration or restorative material [55].

In addition, this technique facilitates the removal of any temporary bonding material still adhering to the side of the abutment tooth [56]. Latta et al. [20] (T#10) investigated the bond strength of two different resin and provisional cements to dentin treated with two adhesive agents and found that the use of a dentin adhesive before provisionalization prevented the temporary cement from affecting the bond strength of the final resin cement to the tooth. Interestingly, they also found that phosphoric acid cleaning for removing temporary cement from a resin-coated dentin surface reduced the bond strength to the same range as that of the negative control group (without resin-coating with temporary cement contamination). They concluded that the acid-conditioning step degraded the adhesive systems, thereby possibly destroying the resin film. As mentioned earlier, phosphoric acid is often used for surface cleaning in the clinical setting. However, the authors clearly claimed that use of phosphoric acid to clean resin-coated surfaces is not recommended [20].

### 3.5.6. Pretreatment 2: inter-oral cleaner

In the field of dental adhesion, functional monomers (salt) containing cleaner are newly commercially available materials developed to recover the original bond strength of luting cements. Functional monomers have hydrophilic and hydrophobic groups, and are therefore effective as cleaners. Additionally, as functional monomers are the components, these cleaners can be used in the mouth. Tajiri-Yamada et al. [11] focused on the use of 10-methacryloyloxydecyl dihydrogen phosphate salt as a new method for removing temporary cement, and reported the excellent decontamination ability of intra-oral cleaners based on multiple examinations (e.g., long-term bond strength test, EDS analysis, contact angle measurement, transmission electron microscopy observations).

Surprisingly, the concept that functional monomers work as a cleaner was evaluated two decades ago. Watanabe et al. [25] (T#15) examined three organic acids—ethyl dihydrogen phosphate, methacryloyloxyethyl dihydrogen phosphate (MEP), and 2-methacryloyloxyethyl hydrogen maleate (MEM)—as cleaners. MEP and MEM contain methacrylate groups, and can therefore be classified as self-etching, self-polymerizing conditioners. The authors recommended MEP as it provides high bond strength and requires no additional rinse step. The authors also reported the positive effects of MEP after 20,000 thermocycles [24].

## 3.6. Integrated perspective

Fig. 1 clearly shows that the simplification of the bonding technique started to be promoted after the establishment of the adhesion technique for dentin in the 1990s. In terms of resin cements, the self-adhesive type has become widely used. In the 2010s, the early de-bonding of a CAD/CAM indirect resin crown became a problem, and the bonding effectiveness of resin cement became an important topic once again. Although the adhesion-inhibitor decontamination steps are contrary to the simple use in clinical practice, both preventing reductions in bonding effectiveness and ensuring adhesion equivalent to that in the laboratory should be emphasized for the evolution of adhesive dentistry. It should also be kept in mind that improved stable bonding leads to a reduction in the amount of preparation required (i.e., tooth loss).

While its simple use has progressed, data have been steadily accumulated on the removal of adhesion-inhibiting factors. Although most research has targeted the direct repair method, the present review focused on luting cement, which is used in indirect restoration. Based on an analysis of removal methods with temporary materials, the decontamination ability of alumina blasting appears to be promising in regard to mechanical cleaning. In fact,

it is often used in clinical practice all over the world. In addition, resin-coating, phosphoric acid and NaOCl treatment, and inter-oral cleaners are considered to be effective as pretreatment for adhesives after tooth preparation and/or before luting.

### 3.7. Future perspective

Surprisingly, blood “application (not contamination)” followed by complete washing with phosphoric acid and NaOCl treatment on a dentin surface improved the effectiveness of resin-dentin bonding [27,57]. Hakogi et al. [57] used a peripheral blood sample collected in a glass tube with anticoagulant (EDTA), and also aspirated distilled water into a glass tube for application as a control. This improvement suggests that biological substances such as saliva and blood may have a positive effect if pretreatment has been carried out (especially for dentin). In this review, saliva and blood were also treated as contaminants, but these may need to be considered differently from materials such as temporary cement. As noted in a previous section (3.2. Saliva contamination), the effectiveness of dental adhesives has also been improving as a result of substantial efforts by numerous researchers, manufacturers, and clinicians.

In the present integrated review, negative points concerning the indirect method affecting adhesion (i.e., contamination) were a focus of attention. The findings showed that contamination by temporary cement was the most severe. In contrast to the conventional indirect method, “1-day treatment”, in which the indirect restoration is fabricated on the same day (mostly within a few hours), makes it possible to eliminate negative factors because there is no need for the use of temporary materials. Currently, digital dental treatment has taken a big step toward the realization of treatment with a high-performance intraoral scanner. In the future, dentistry will push forward with the achievement of fully digital treatment. However, before its realization, tooth preparation and luting will be the final analog procedure.

## 4. Conclusion

Based on a comprehensive literature review on the effects of decontamination due to potential vulnerabilities after contamination of dentin luting surfaces, we can draw the following conclusions:

- 1 It has been reported that bonding effectiveness is reduced due to residual adhesion inhibitors such as saliva, blood, hemostatic agents, and temporary/provisional cements. The negative effects differ depending on the experimental system, decontamination timing, and materials. Self-etching and self-adhesive systems tend to be affected more negatively by adhesion inhibitors than by etch and rinse systems.
- 2 Mechanical cleaning, chemical cleaning, and a combined method were evaluated as methods for decontaminating adhesion inhibitors. Although many studies have investigated cleaning with an ultrasonic scaler or rotating brush, which are mechanical methods, conflicting effects have been reported.
- 3 Phosphoric acid was examined as chemical (acid) cleaning method. Some studies have concluded that this strong acid may exert negative effects and thus recommend mild acid for decontamination. To avoid negative effects, NaOCl application after phosphoric acid etching is recommended depending on the situation.
- 4 Temporary/provisional cement is difficult to remove from dentin compared with other adhesion inhibitors; therefore, many cleaning methods (e.g., mechanical, chemical) have been evaluated. Alumina blasting has been examined as a mechanical cleaning

method in a relatively large number of experiments, and most reports have confirmed its effectiveness.

- 5 Adhesion inhibitors can be easily removed from resin-coated dentin surfaces, which indicates that resin-coating is also effective as a method to prevent the deterioration of adhesiveness due to adhesion inhibitors.
- 6 The intra-oral cleaner containing functional monomers, which has become commercially available in recent years, is a promising method because it can easily and effectively remove temporary adhesive material.

## Conflicts of interest

None.

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## Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.jdsr.2021.08.001>.

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