A clinical view of the main steps of tooth/composite resin adhesion techniques

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Abstract: The aim of this paper was to present a review of the main adhesive techniques for direct restorations and to propose an application protocol and clinical indications. With this purpose, different adhesive strategies, adhesive system components performance and their interaction with the dental tissue were presented. Clarifying to the dental surgeon about the different adhesive techniques and their indications may contribute to produce better clinical results. **Keywords:** Dentin. Dental enamel. Dental bonding. Adhesiveness.

How to cite: Alexandre RS, Araújo TSB, Chessa TM, Santos ES, Cunha FP, Nóbrega AS, et al. A clinical view of the main steps of tooth/composite resin adhesion techniques. J Clin Dent Res. 2017 Apr-June;14(2):51-61.

Submitted: February 20, 2015 - **Revised and accepted**: March 20, 2017.

DOI: https://doi.org/10.14436/2447-911x.14.2.051-061.oar

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» The authors report no commercial, proprietary or financial interest in the products or companies described in this article.

INTRODUCTION

In order for restorative procedures to have a long durability, it is essential to achieve an effective union between tooth and restorative materials.[1] Since the beginning, a major concern was to find a restorative material that presented an adequate marginal sealing, biocompatible and with a good abrasion resistance. Thus, the adhesive era was one of the main advances of dentistry.[2]

However, the effectiveness of the technique was only possible after the findings of Buonocore and after Nakabayashi,[3,4,5] who introduced the technique of acid conditioning, which reduced the lack of union of the restorative materials with the dental structures.[6]

However, the main clinical failures that still occur are more related to adhesive systems than to composite resins, such as in cases of marginal infiltration, pulp irritation and postoperative sensitivity.[2]

Adhesion of restorative materials on dentin is considered more difficult than on the enamel, due to the humidity present in the dentinal tubules and its composition that is organic. Thus, the union of the resin to the enamel is more favorable, since the acid conditioning creates microporosities where the adhesive penetrates, adhering mechanically (Fig 1).[7,8,9]

A series of adhesive generations has been developed, aiming to simplify the application technique, which did not contribute greatly to increased durability of the union.[6,8]

There are four groups of adhesive systems (Table 1). The main adhesive group is the conventional three-step system, which can be very efficient in the union to the dentine; however, there are some factors that can jeopardize this union. Critical steps must be considered, such as controlling of the contact time of phosphoric acid with dentin and the humidity control, avoiding to exceed the drying that can lead to the collapse of the collagen network.[6,10]

In order to simplify the clinical procedures, the two-step systems emerged, which have the separate acid and combine the primer and the adhesive together; soon afterwards, self-etching adhesive systems with two steps and single step were launched.[7,11,12,13,14,15,16,17,18,19,20,21] Finally, the Universal adhesives have emerged, which are a version of conventional two-step adhesives plus acid monomers. Thus, they may or may not be used with prior acid attack.[22]

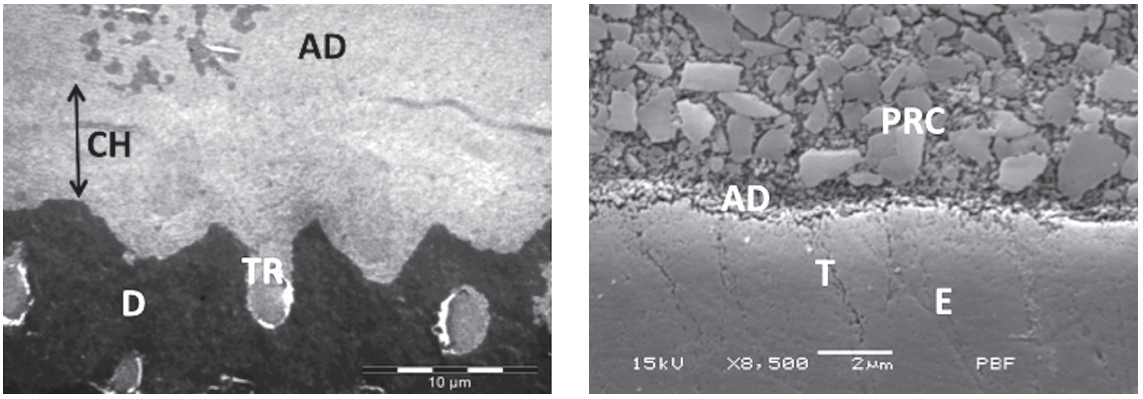

Figura 1: Camada híbrida e imbricamento do adesivo convencional no esmalte.

Table 1: Application protocol.

	Initial treatment of the dental substrate	Wash with water	Drying and moisture control	Application of primer	Application of the adhesive (Bond) or primer/adhesive	Photoactivation Minimum power of 600 mW / cm²	Insertion of composite resin
Dentin 15 sec. Enamel 30 sec.	20 sec.	moist dentin dry enamel	Apply throughout the dentin Wait 20-30 seconds (evaporate solvent)	Apply actively and wait 20-30 sec.	10-20 sec.	· 10-20 seg.	Incrremental technique or single increment with Bulk-fill resins
Dentin 15 sec. Enamel 30 sec.	20 sec.	moist dentin dry enamel	-	Apply actively and wait 20-30 sec.	10-20 sec.	· 10-20 seg.	
Dentin 15 sec. Enamel 30 sec.	20 sec.	moist dentin dry enamel	-	Apply actively and wait 20-30 sec.	10-20 sec.	· 10-20 seg.	
Active application of primer acid for 20 seconds in dentin and enamel	-	-	-	-	10-20 sec.	· 10-20 seg.	
Dentin15/ Enamel 30 or just enamel 30 sec.	20 sec.	moist dentin dry enamel or both dentin and enamel dry	-	Apply actively and wait 20-30 sec.	10-20 sec.	· 10-20 seg.	

Besides all the care during application of the adhesive system, it is essential to use an adequate restorative technique, with adequate isolation of the operative field, because the adhesion effectiveness includes the correct treatment of the dental surface, avoiding the contamination of operative field. So is the dentist responsibility to create appropriate conditions for the action of the adhesive with the dental tissue to be succeed.[2]

ADHESIVE SYSTEMS HISTORICAL EVOLUTION

The first adhesives emerged in the 80's. The first-generation adhesive system consisted of an interaction of the glycerophosphoric acid dimethacrylate which had a bifunctional molecule to the hydrophilic phosphate group, capable of interacting with the calcium ions of the hydroxyapatite of the dentin, together with the methacrylate group adhered to the restorative composite methacrylate group. However, this chemical union was considered weak.[23]

The second generation came in the same decade; this generation of adhesive system consists of preconditioning the dentine with 40% orthophosphoric acid, which enabled the formation of resinous projections (tags) in the interior of the tubules. This procedure did not completely remove the smear, but it was considered better than the first adhesives, since it obtained adhesion in conditioned enamel and dentin.[23]

The next ones were the systems that have started using the "primer", which increases the wetting capacity of the dentin and are applied before the bond or adhesive, producing greater adhesion efficacy, evident reduction of marginal infiltration, increased bond stability to dentin. However, such technique presents a more complex application.

Then, the first conventional 3-step adhesives that remove the smear have emerged, that demineralize dentin surface and expose the network of collagen fibers for subsequent impregnation of the demineralized area, by hydrophilic monomers. The hydrophilic "primer" is responsible for dampening, penetrating and filling any demineralized structure around the collagen, forming the hybrid layer structure (Fig 1).[24,25]

Right after, the bond is applied over the "primer" to complement the sealing process of the demineralized structures and to bond to restorative material[26] (Fig 1). To date, such system is considered the gold standard of dentin adhesion systems.[6,14,27]

In order to simplify adhesive systems, conventional simplified two-step systems have been developed, Wherein the agent having affinity for water and proteins (primer) is mixed with the bonding agent in a single vial. In this generation of adhesives, the function of removing the smear continues in a separate step of conditioning with phosphoric acid.[6] Such adhesive has a great reduction in the time of application of the adhesive technique, nevertheless, its dentin sealing ability and resistance to water degradation are lower.[6,18,28,29]

The next adhesive system to be launched was the 2-step self-etching, they are the latest adhesive systems and do not remove the smear layer and the monomers of the primer have an acid character, capable of demineralizing the dentin and forming the hybrid layer (Fig 2). On this way, we eliminate the step of conditioning with phosphoric acid, washing and humidity control of dental tissues. Although these adhesives form a smaller hybrid layer (Fig 2) than the conventional adhesives, Self-etching adhesives produce bond strength similar to conventional ones.[18,30]

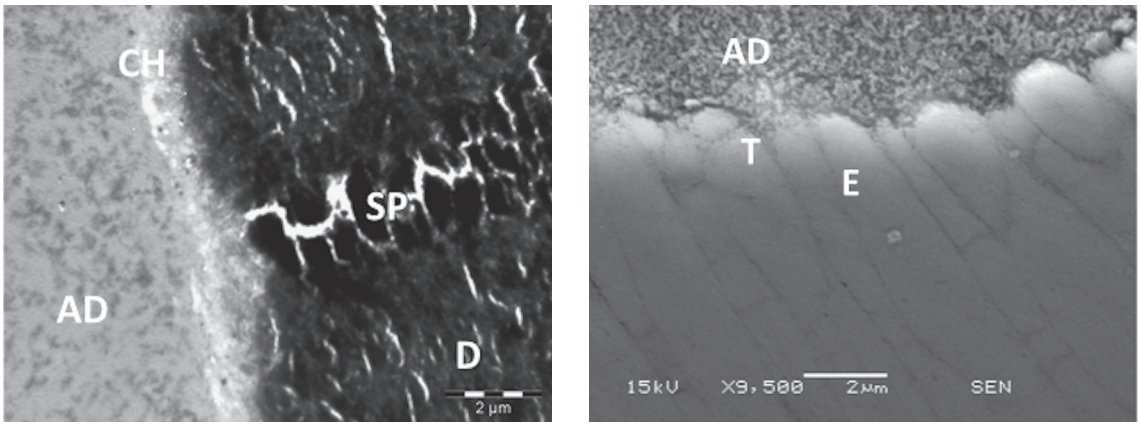

Figura 2: Camada híbrida e penetração do adesivo autocondicionante no esmalte.

Such steps are considered critical points,[31] The error in the procedures can lead to the collapse of the collagen network, inadequate tissue hybridization and adhesive polymerization.[6] Because these systems are applied directly to the dry dentin and the acid treatment of the dental tissues are not dissociated from the penetration of the resinous monomers, it avoids a serial of problems. Besides that, the application of the bonding agente separeted from the primer it is a great advantage of this system (Fig 2). On the other hand, we have a union with the enamel that still raises doubts in the clinicians, although several works show similarities of union in abrasion enamel.[7,32]

More simplified versions of this system (single-step self-etching) have been released by manufacturers, but have not shown satisfactory results over time.[16,33,34,35,36,37,38] The deficiency of this group of adhesives falls to its low pH and high permeability.[39,41,42,43] Thus, the adhesive does not exhibit effective polymerization, which consequently leads to poor bond strength and high hydrolytic degradation.[18,28,29,44,45]

Aiming to overcome the problems of 1-step self-etching, manufacturers have launched Universal or Multi-Mode adhesives. These adhesives were developed to be applied either with the acid conditioning technique or as one-step self-etching. Its formulation is closer to that of conventional 2-step adhesives, but with the addition of acidic monomers of moderate pH (pH 2-3).[46] Universal adhesives that present in their formulation the 10MDP acid monomer have been shown to be more efficient.[22,47,48] The use that has shown better clinical and laboratory results is the use of the technique of selective acid conditioning only of the enamel, especially in posterior restorations or that present a great amount of enamel in the margins.[48,49]

GENERAL CONSIDERATIONS

The deep knowledge of dental structures becomes extremely necessary, because the chemical and structural differences of each tissue have different interaction with the adhesive systems.[6,26] Enamel, by having a high mineral content, is considered the least worrying. [24]

It is possible to affirm that the self-etching adhesive system, responsible for revolutionizing the restorative technique, has a better performance in the dentin and relatively lower postoperative

sensitivity, But a great challenge is faced when dealing with enamel adhesion.[50] The presence of the enamel's aprismatic layer can act as a resistant acid layer, hindering the action of acidic monomers and adhesion[7,51] (Fig 2). Some authors suggest the removal of the layer of enamel with a diamond tip or use phosphoric acid only on the edges of enamel, known as adhesion technique with selective acid conditioning.[52]

Several authors agree that the union of the conventional adhesive systems to the enamel is satisfactory because it is a highly mineralized tissue, the union of hydrophobic substances such as resin adhesives is facilitated; noting the absence of enamel microleakage regardless of the type of adhesive system used.[8,13,20,53,54,55]

The dentin composition is 50% of inorganic material, 30% of organic material and 20% of dentin tubules and odontoblastic extensions and dentinal fluid.[6,56] These characteristics hinder the penetration of monomers and their co-polymerization inside the tissue. For this to be possible a series of hydrophilic components (primer) need to act first so that the hydrophobic components can penetrate and impart adequate (adhesive) strength[57]. In addition, we must consider the need to evaporate the solvent prior to the polymerization of the adhesive. This component is very useful during the penetration phase of the hybrid layer, but its permanence may cause problems for polymerization, producing areas most susceptible to hydrolytic degradation, marginal microleakage and postoperative sensitivity.[18,58,59]

The smear layer should be considered for adhesion on two aspects. One is its natural protective function, which would obliterate the dentinal tubules and reduce dentin permeability more efficiently than any varnish;[60,61] and would interfere in the adaptation of the dental materials in the dentin and would also serve as deposit of microorganisms and their products, causing pulp injury.

Thus, the use of the self-etching system that is applied over the relatively dry smear and dentin avoids certain problems associated with the use of separate steps. These self-etching systems simultaneously increase dentin permeability, due to its intrinsic acidity, and facilitate the penetration of the resinous monomers into the microporosities produced in the dentin. In addition, there is the chemical bond between the acid monomer and the hydroxyapatite that surrounds the collagen fiber, which generates greater stability of the union interface.[6,21,62,63] The step of conditioning the dentin separately from the penetration of the adhesive may generate a discrepancy between the depth of demineralization and the penetration of the bond, generating postoperative sensitivity and future degradation from collagen.[64,65]

Among the self-etching adhesives, the best performance is obtained with the two-step adhesives, when compared to the one-step adhesives, which are usually marketed in two vials. The bond values obtained by the two-step adhesives are larger, matching the conventional three-step adhesive system.[8,45,63]

The process of adhesion to dental structures has been exhaustively studied in the last decade, and the two-step self-etching systems become a safe option, especially when the dentin cavity predominates, such as restorations in posterior teeth.[20,38,63,66,67.]

The combination of the conditioner and primer (self-conditioning primer) or primer and adhesive (self-etching adhesive) reduced the number of operative steps. However, this simplification has not generated such encouraging results in the durability of the union.

Although the laboratory results point to similar effectiveness among the different techniques, the initial clinical results suggest that the use of a hydrophobic layer separately from the primer produces superior results. Moreover, one difficulty of this adhesives is the adhesion to enamels without preparation. Many clinicians associate selective acid etching of the enamel to self-etching adhesives, however, the risk of accidentally conditioning the dentin is imminent which may be a problem for this self-etching adhesive because of its incompatibility with the acid etching technique.

Universal adhesives have been shown to be an efficient option for direct restorations mainly on posterior teeth. Such adhesive presents low postoperative sensitivity and relative hydrolytic stability. The main reasons for this performance are the use of acidic monomers with moderate pH. Such monomers, such as MDP, exhibit an excellent degree of polymerization, chemical bonding to the hydroxyapatite in both dentin and enamel. However, the best results of these universal adhesives suggest the conditioning of the surrounding enamel to the cavity. Thus, even if the clinician inadvertently conditions the dentin, this would be irrelevant since the adhesive has components compatible with the acid conditioning technique. This fact would be quite detrimental to one- and two-step self-etching adhesives.

Thus, even with the various laboratory researches that exist nowadays they have limitations due to the impossibility of simulated oral conditions. In this way there is a need for more clinical tests for a more reliable understanding of these various systems.

SEQUENTIAL CLINICAL STEPS OF ADHESIVE SYSTEMS

3-STEP CONVENTIONAL

It is known that dentin has water and that this is an important factor in adhesiveness, because the moisture keeps the collagen network permeable, facilitating the infiltration of the resinous monomers of the adhesive[58,59] (Table 1 and Fig3). Thus, the phosphoric acid conditioning is performed in order to achieve an opening of the dentinal tubules, and it should be washed through a spray of water and air, remembering that the water should be filtered, so that there is no contamination of the preparation. The contact time of the acid in the enamel and dentin are 30 and 15 seconds respectively.[2]

Subsequently, the Primer (bifunctional monomers) that performs the entanglement between the wet surface of the conditioned dentin and the adhesive agent is applied. Thus, the network of collagen fibers and the evaporation of water accumulation will be stabilized with the aid of the solvent present in the primer. As a result, there is a relative increase in the free surface energy of the dentin, making it able to obtain a good interaction with the adhesive.[45]

The next step is the application of the adhesive that will form a uniform and dense hybrid layer extending from the dentin zone unaffected by acid etching to the surface of exposed collagen fibers.[6,60]

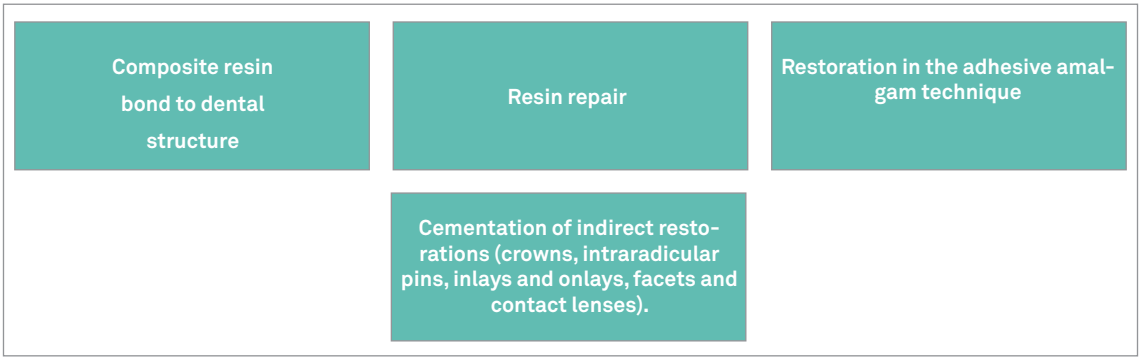

Figure 3: Indication of conventional 3-step and 2-step adhesive systems.

2-STEP CONVENTIONAL

The manufacturers make available primer and adhesive in single flask,

the conventional two-step procedure undergoes the same three-step clinical procedure by counting as a differential one step less, as the primer will be available along with the adhesive[2] (Table 1 and Fig 3).

It is important to be concerned with acid conditioning, as its ineffective action will create areas where surface porosity will be deficient without penetration of the resinous agent, which would compromise adhesion, resulting in inefficient marginal sealing and possible postoperative sensitivity.[17,26]

2-STEP SELF-CONDITIONING

It consists of a primer and bond acid, and may be single step (Table 1 and Fig 4). In this type of procedure there are no separate acid conditioning steps, the substrate mofication is ptimer responsability, thus having the function of making the dental structure capable of developing an interaction with the adhesion agent. The primer must have a pH low enough to demineralize the hydroxyapatite crystals of enamel and dentin.[6,8,61]

Even though acidic primers develop a function equivalent to phosphoric acid, it results in a large difference between traditional and self-etching systems for not being washed, because the self-etching process does not have the need to remove the dentin sludge, using the smear layer as a dentin substrate.[6,61]

These adhesives have in their composition high concentrations of more acidic monomers in the primers, so they are able to dissolve and/or modify the smear layer and the surface portion of the underlying dentin. Better sealing could occur with such adhesives, since there would be no discrepancy between the depth of conditioning and the extent of infiltration of the resinous monomers in the substrate. An advantage of this type of adhesive is that sealing would result in minor or no postoperative sensitivity[37,62] After the primer, a thin and even layer of the adhesive agent should be applied.[2]

SINGLE-STEP SELF-CONDITIONING

All components are applied together (acid, primer and adhesive). It can be sold in single or in two separate flask.[62] When separated into two vials, one drop of each vial is dispensed

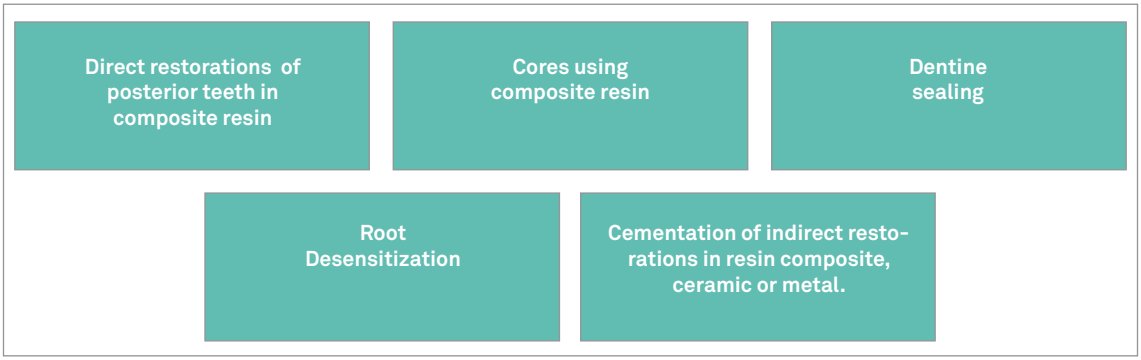

Figure 4: Indications for use of 2-step self-etching adhesive systems

and mixed into a container as soon as it is to be used, also performing the hybridization in a single step (Table 1 and Figure 4). In this the smear layer is also used as dentin.[2]

UNIVERSAL ADHESIVE

The prior acid conditioning is optional, because these adhesives have self-etching components. However, a suggested approach is the conditioning of the enamel with 35% phosphoric acid for 15-30 seconds. Thus, the more superficial layer of the enamel is removed by the acid, allowing a more efficient micromechanical union added to the chemical union of the acid monomers (Table 1).

Thus, the technique is the conditioning of the enamel margin for 15-30 seconds, wash for 20 seconds and dry. Because dentine is not conditioned, it is not necessary to control its moisture. Then, we actively apply the adhesives for 20 seconds throughout the cavity, wait 20 seconds and photopolymerize for 10 seconds (Table 1).

CONCLUSION

The commercially available adhesive systems show good clinical performance if used within the statement and correct technique. The adhesives with acid conditioning are more sensitive to the technique, with greater chances of error during their application. The self-etchants present less technical sensitivity, but are not unanimous in cases of large amounts of enamel for adhesion. The simplification of the technique in any of the systems produces a considerable reduction in the final adhesion quality.

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