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Adhesive Systems: Considerations About Solvents

Sistemas Adhesivos: Consideraciones Acerca de Solventes

Jovito Adiel Skupien*; Tathiane Larissa Lenzi*; Marciano Freitas Borges*; Jeferson da Costa Marchiori;
Rachel de Oliveira Rocha** ; Alexandre Henrique Susin**; Tissiana Bortolotto*** & Ivo Krejci*****

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ABSTRACT: By definition, solvents are substances capable to dissolve or disperse one or more substances. They are responsible for dilution of resin monomers, improving its diffusion throughout the demineralized dentin matrix and represent an important role in removing moisture from the substrate during the evaporation. Usually, the solvents used in adhesive systems are water, ethanol and acetone. To improve bonding in dental structure, there are some kinds of strategies of application to reach a better performance of adhesive systems. Some strategies seem to be favorable to obtain maximum benefit from the solvents, such as active application, increase of application time, increase of the number of adhesive layers and increase of time of application of air-jet. However, studies that perform a better adhesion at long-term must be achieved.

KEY WORDS: solvents, dental adhesives, dentin.

REVIEW OF LITERATURE

Adhesive systems are widely used in clinical practice and by definition they are responsible for establishing the bonding between restorative material and dental structure (Carvalho, 2004). Currently, according to the number of steps of use, they can be classified into one, two or three steps, depending on the way of procedure and number of bottles (Van Meerbeek *et al*., 2003).

There are basically two kinds of commercially available adhesive systems: total-etching (TEAS) and self-etching (SEAS) adhesives. TEAS use previous etching and can be found in two or three steps. Already the SEAS associate the etching to primer or primer/ bonding.

Ideally, the adhesives should be formulations based on hydrophobic monomers and high molecular weight, without additives such as solvents and water. However, due to the necessity for adhesive to penetrate into microporosities of the dentin, substrate inherently wet, hydrophilic resinous diluents and solvents were incorporated into the adhesive. Thus the liquid to be spread uniformly over a solid surface, the surface tensile of liquid must be less than the energy free surface of the substrate (Erickson, 1992; Degrange *et al*., 1993). The low viscosity of primers and/or adhesive resins is partly due to the dissolution of the monomers in a solvent and will improve ability of diffusion into the micro-retentive tooth surface (Van Meerbeek et al.). In fact, high values of bond strength to dentin, similar to those achieved in enamel, were obtained after the development of hydrophilic monomers and their association with organic solvents (Van Meerbeek *et al*.; Carvalho; Brackett *et al*., 2008; Burrow *et al*., 2008).

By definition, solvents are substances capable to dissolve or disperse one or more substances (Morryson & Boyd, 1973). They are responsible for dilution of resin monomers, improving its diffusion throughout the demineralized matrix and represent an important role in removing moisture from the substrate during the evaporation (Abate *et al*., 2000; Reis *et al*.,

* DDS, Master Degree Student - Federal University of Santa Maria, Santa Maria, RS, Brazil.
** DDS, MSc, PhD, Professor, Department of Restorative Dentistry – Federal University of Santa Maria, Santa Maria, RS, Brazil.
*** DDS, MSc, PhD, Division of Cariology and Endodontology - School of Dentistry – University of Geneva.

2003). In adhesive systems, water (boiling temperature 100° C), ethanol (78.3º C) and acetone (56-58° C) are solvents frequently used (Van Landuyt *et al.,* 2007).

Acetone is able to remove water from the substrate (Tay *et al*., 1998). However, it cannot prevent the consequent collapses of collagen fibrils when it is used over a dry dentin, unlike water used as solvent. However, significantly smaller values of bond strength to dentin were found using such systems, as well as non-homogeneous hybrid layer and an excess of moisture of the substrate (Abate *et al.*).

A large amount of solvent (greater than 20 wt. %) dilutes the concentration of monomers and separates the polymer cross link creating large physical spaces between the reactive species during the polymerization (Cho & Dickens, 2004; Cadenaro *et al*., 2008; Ye *et al*., 2007). It has been demonstrated that SEAS also reduce the degree of conversion (Jacobsen & Söderholm, 1995) and their mechanical properties when water is added to them (Ito *et al*., 2005a, Hosaka *et al.,* 2007).

The extensive use of solvents in adhesive systems becomes susceptible to formation of a poor hybrid layer. The solvent may be responsible for the formation of droplets/blisters. There are several hypothesis to support this statement, like that the simplified adhesives form a semi-permeable membranes after polymerization (Tay *et al*., 2002) causing, due to osmotic pressure, the passage of dentinal fluid to adhesive interface, providing the accumulation and resulting in the formation of blisters. Another hypothesis, speculated by Chersoni *et al.* (2005) reports that waste of water in the dentin would be responsible for the droplet formation, as a result of the saturation by osmosis, provided by etching, being able to reach the adhesive interface due to permeability after polymerization.

A study conduced by Ferrari *et al.* (2008), which objective was to clarify how the formation of blisters occurs in adhesive interfaces in dentin, demonstrated that the use of adhesives of 2 and 3 steps with prior etching, and, self-etching adhesives (2 steps), result in an interface with little formation of blisters, and when they occur, it is probably due to residues of solvents retained into the interface. Even, it emphasizes the fact that single-step self-etching adhesives are more favorable to formation of these droplets due to the phase separation and insufficient evaporation of solvent (Van Landuyt *et al*., 2005).

In order to have a better evaluation of phase separation phenomenon, Gaintantzopoulou *et al*. (2008) used 3 adhesive systems and changed the method of evaporation of solvent (mild and strong air drying). All adhesive systems tested showed phase separation and consequently the formation of blisters, but the use of a strong air drying was able to reduce the degree of separation.

In dental adhesion, several factors are evaluated to reach the appropriate bonding: number of layers of adhesive (Arisu *et al*., 2009; Ito *et al*., 2005b), different strategies for application (Pivetta *et al.*, 2008; Lührs *et al*., 2008; Cilli *et al*., 2009; Reis *et al*., 2007), high degree of conversion (Kanehira *et al*., 2006; Cekic-Nagas *et al.*, 2008) kind of monomer used (Van Landuyt *et al*., 2008). Recently, Lima *et al.* (2008) investigated the influence of different water concentration in an experimental self-etching primer system on the microtensile bond strength to dentin. The study demonstrated that the water concentration in the primer influenced on the bond strength of tested adhesive system, corroborating the importance of solvent in the composition of adhesive systems.

The use of air-jet after the application of the adhesive improves the evaporation of solvent and water, reducing the thickness of adhesive layer and becoming more uniform (Spreafico *et al*., 2006). The time of air-jet application should be observed according to the manufacture's instructions and it can vary between 5 and 10 seconds. The solvent remainder in the adhesive can compromise its polymerization due to dilution of monomers and result in permeability of adhesive interface (Hashimoto *et al*., 2004; Cho & Dickens).

However, variations in the duration of air-jet can occur routinely in clinical practice. Some studies evaluated the effect of air-jet time on dentin bond strength of SEAS. Most of the studies demonstrated that the increasing air-jet time results on higher bond strengths values (Jacobsen *et al.*, 2006; Sadr *et al.,* 2007; Furuse *et al*., 2008; Ikeda *et al*., 2008). The fact that extending the air-jet times provides more evaporation of organic solvent and water can be justified on that. Moreover, Chiba *et al.* (2006) reported that the absence of air-jet had a negative influence on dentin bond strength of SEAS.

The formation of hybrid layer has been accepted as responsible for adequate resin/dentin adhesion (Pashley & Carvalho, 1997). Among other factors, the rate of diffusion of monomers to demineralized dentin, providing the micromechanical retention, can improve bond strength. The diffusion occurs due to the presence of solvent capable to infiltrate within the collagen network, keeping the monomers in the spaces previously occupied by minerals. In order to reach a higher monomer infiltration, the time of contact between adhesive systems and demineralized substrate should be increased.

The effect of time of application of the adhesive in bond strength was also evaluated in several studies (Cardoso *et al*., 2005; Toledano *et al*., 2007; Reis *et al.*, 2008). A study of Toledano et al. evidenced that by increasing the time of application, the bond strength was improved when simplified adhesive systems were used.

Cardoso et al., used two adhesive systems with different solvent and examined the effect of the time of application increasing in microtensile bond strength and correlating with rate of adhesive evaporation. It was verified that when increasing the application time, the bond strength presented better results and the time of application depends on the kind of solvent used in adhesive system.

A study performed by Reis et al., to evaluate the influence of different times of application of different adhesive systems (40, 90, 150 and 300 seconds) on bond strength, evidenced that more evaporation of solvent occurs associated with increased time resulting in higher bond strength values. The results obtained in these studies show that a better penetration of monomers into demineralized substrate is due to higher evaporation of organic solvent and water before the photocuring of adhesive.

In the same way, the application of more than one adhesive layer contributes for a more effective adhesion, especially in dentin (Ito *et al*., 2005b; Albuquerque *et al*., 2008). As the solvent is evaporated to each adhesive application, the co-monomer concentration increases improving the quality of the hybrid layer and the correlation of adhesive layer cured versus no cured due the oxygen inhibition (Kim *et al*., 2006).

The application of multiple adhesive layers does not contribute to increase the adhesive thickness, but improve the quality of the adhesive layer (Hashimoto *et al*.). Adhesive systems as G-Bond (GC, Tokyo, Japan), which contain water and acetone as solvent, demonstrated lower bond strength values (Albuquerque *et al*.). As the evaporation of acetone is faster than water, the gradient of water and the monomer concentration increase proportionally, minimizing even more the water evaporation. This situation can be worse ahead of a double adhesive application, increasing the water concentration in the adhesive layer and reducing bond strength values.

As mentioned previously, the solvent is responsible for carrying resinous monomer to demineralized dentin to involve collagen fibrils. The decreases of gradient concentration of solvent increase the viscosity of the adhesive system, jeopardizing such function. Furuse *et al*., evaluated the influence of the degree of evaporation of solvents in the bonding capability. The authors concluded that some systems are sensible to degree of evaporation of solvents and still suggest that other studies must be performed in order to reduce technical sensitivity and improve the performance of adhesive systems.

To show the importance of correct application of adhesive systems, Cavalheiro *et al.* (2006) tested in vitro the effect of errors of primers application in dentin permeability. Using 3 step adhesive systems, the authors simulated 4 errors in application: low time of application of primer and immediate drying; no application of primer; application of primer without posterior drying; rigorous drying of primer. As a control, the primer application was performed according the manufacturer's instructions. It was verified that in order to obtain an adequate sealing of dentin tubules, it is necessary to follow the manufacturer's instructions, in accordance with Peutzfeldt & Asmussem that demonstrated to reach a satisfactory result: the use of adhesive systems must be made as the manufacturer advice.

The kind of solvent present in adhesive system can be responsible for determining how humidity should be the substrate. It is important to verify what kind of solvent is present in adhesive system formulation, for surface wet pattern to be adjusted and thus provides a better performance of adhesive system. However, besides the solvent used, monomer, initiator and others also must be analyzed (Reis *et al*., 2003).

CONCLUSION

Solvents are essential to promote an adequate adhesion. Although, the ideal concentration cannot be determined yet, due to different formulations and substrates in which they are tested. Some strategies seem to be favorable to obtain maximum benefit from the solvents, such as active application, increase of application time, increase of the number of layers and increase of time of application of air-jet. All these factors improve solvent evaporation in adhesive systems and ensure bonding in short-term performance. However, studies that perform a better adhesion at long-term must be achieved.

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RESUMEN: Por definición, los solventes son sustancias capaces de disolver o dispersar una o más sustancias. Son responsables de la dilución de los monómeros de la resina, mejorando su difusión en toda la matriz de la dentina desmineralizada y representan un papel importante en la eliminación de la humedad del sustrato durante la evaporación. Por lo general, los solventes utilizados en los sistemas adhesivos son agua, etanol y acetona. Para mejorar la adhesión en la estructura dental, hay algunos tipos de estrategias de aplicación que permiten alcanzar un mejor desempeño de los sistemas adhesivos. Algunas estrategias parecen ser favorables para obtener el máximo provecho de los solventes, como la aplicación activa, aumento del tiempo de aplicación, el aumento del número de capas de adhesivo y el aumento de tiempo de aplicación del chorro de aire. Sin embargo, investigaciones que permitan realizan una mejor adherencia a largo plazo debe ser realizadas.

PALABRAS CLAVE: solventes, adhesivos dentales, dentina.

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Correspondence to:
Jovito Adiel Skupien
Federal University of Santa Maria
Mal. Floriano Peixoto, 1184, sala 114
Santa Maria – RS
BRAZIL

Zip Code: 97015-372
Phone : 55 55 99638451
FAX :55 55 32209268

Email address: jovitoodonto@yahoo.com.br

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