The effect of application errors of an acetone-based adhesive on bond strength to dentin.

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بسم الله الرحمن الرحيم

" قَالُواْ سُبْحَٰنَكَ لَا عِلْمَ لَنَآ إِلَّا مَا عَلَّمْتَنَآ ۖ
إِنَّكَ أَنتَ ٱلْعَلِيمُ ٱلْحَكِيمُ "

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Dedication

To my family, for their endless love and support

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Adhesive dentistry has evolved dramatically towards a trend eliminating as many steps as possible in the bonding protocol [1]. Technique simplification has been a goal of researchers and manufacturers of adhesive systems. Van Meerbeek, in 2003[2] proposed a simple classification based on the interaction of adhesives with dental substrate and number of steps, etch-and-rinse (two and three-steeps adhesives), self-etch (one-and two-steep adhesives) and glass ionomer. Self-etch adhesives have attracted considerable interest due their great advantages in simplifying the bonding procedure and reducing the potential for tooth sensitivity [3].

Although the one-step, self-etch adhesive system is marked as simplified, a more complex chemistry is necessary to blend the hydrophilic and the hydrophobic monomers [4]. One-step self-etching adhesives are complex mixture of hydrophilic functional monomers and hydrophobic cross-linking monomers dissolved in organic solvent (ethanol or acetone) and water [4]. Solvents such as acetone and ethanol are necessary to dissolve both hydrophilic and hydrophobic monomer into one phase [5]. Solvents help in the penetration of the bonding agents into the demineralized, collagen rich dentin surface by lowering the viscosity of the solution and have water chasing effect[6]. Water is the main component of these adhesives since it produces acidic H^+ ions.

Acetone (boiling point: 65.5°C) has a relatively high vapor pressure. Reduction in the bond strength of acetone-based adhesives after repeated opening of the container, which has been considered to be due to the loss of acetone by evaporation from the container[7]

Hydroxyethylmethacrylate (HEMA), was believed to be a valuable component in self-etching dentin bonding as it keeps all components in a homogenous solution. Some of the drawbacks of HEMA are retaining water within the adhesive layer which in turn leads to poor mechanical properties of the adhesive layer[8]. Phase separation among adhesive compositions was confirmed as droplets entrapped during solvent-evaporation from HEMA-free adhesives [9]. This phenomenon could be explained by the evaporation of solvents, such as ethanol and acetone, which affected the balance of solvents and resin monomers and caused water to separate from other compositions of the adhesive[9].

The questionable stability of single-bottle self-etching adhesive, has been pointed out as an inherent disadvantage[10]. The instability of these single-bottle self-etching adhesives systems from the hydrolytically unstable acrylic ester type and methacrylic acid ester type monomers used in these formulations, thereby causing the formulations to degrade and resulting in poor shelf lives[10].

Thus correlating the effect of dispensing time and stirring of an acetone-based self-etching adhesive on bond strength to dentin was found beneficial.

Acetone based self-etching adhesive

All-in-one or one-step self-etching adhesives is the most simplified, adhesive protocol that can clinically be employed to bond composite to tooth enamel and dentine. Less application steps reduce manipulation time and technique sensitivity, and may so improve bonding effectiveness in daily clinical practice [(11)]. Self-etching agents were introduced to eliminate the conditioning, rinsing, and drying steps, which are technique sensitive and difficult to standardize under clinical conditions [(12)].

All in one adhesive system combines both hydrophobic and hydrophilic monomers which are blended, with a relatively high concentration of solvent, required to keep them in solution[(13)]. Theoretically, the use of hydrophilic resins as dentin adhesives would induce water sorption, thereby increasing adhesive permeability via nanoleakage channels, and this water would potentially be available for hydrolysis[(14)]. Contemporary one-bottle self-etching adhesives and two-step total-etch adhesives generally have higher hydrophilicity than the water-free adhesives of two-step self-etching, or three-step total-etching[(15)].

Solvents are substances capable of dissolving or dispersing one or more substances[(16)]. 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[(17)]. These solvents present different volatilities and are added to adhesives in concentrations ranging from 30 to 80% [(18)].

This variation is due to fact that more volatile solvents are commonly added in higher concentrations[19]. Different solvents presented in simplified bonding agents are responsible for either carrying excess water out and infiltrating resin monomers into interfibrilar dentin[20]. Benefits offered by solvents rely on their properties of improving substrate wetting, aiding to restore the collapsed collagen fibrils and to stiffen them[20].

Water, ethanol and acetone are basically the main solvents in commercial formulation[21]. Water is a polar solvent with a high dielectric constant, and is capable of breaking hydrogen bonds between collagen fibrils[22], as well as re-expanding the collapsed and shrunken collagen network[23]. Its dissolving capacity is greatly determined by its ability to form strong hydrogen bonds[23], and is essential in both etch-and-rinse and self-etch adhesives. In etch-and-rinse adhesive, water has a plasticity effect on the collagen fibrils and decreases the stiffness of the collapsed fibrils, which is important for the expansion of the dried dentin collagen[24]. In self-etching adhesive it is the main component, providing an ionization medium to facilitate self-etching activity to occur[24]. Solvents such as ethanol or acetone are added to the solution. However, its dielectric constant is lower than that of water[23]. Vapor pressure is the pressure of a vapor in equilibrium with its non-vapor phases. All liquids have a tendency to evaporate to a gaseous form, and all gases have a tendency to condense back into liquid form at a given temperature[15]. Acetone presents higher vapor pressure (184 mm Hg at 20°C) when compared with ethanol (43.9) and water (17.5), which translates into faster evaporation of the solvent for acetone-based adhesives in clinical

settings[25]. Its higher vapor pressure provides better evaporation by air-drying. Usually ethanol is a co-solvent for water, water-alcohol mixtures are known to form hydrogen bonds between their molecules. Ethanol-water mixture is called an azeotrope, which is a mixture of two or more liquids whose proportions cannot be altered by simple distillation[26]. This happens because when an azeotrope is boiled, the vapour has the same proportions of constituents as the unboiled mixture, which results in a greater evaporation of water-ethanol aggregates than of pure water, because ethanol (96%) / water boils at 78.1°c[26].

The role of acetone in the bonding solution is three-fold: acetone lowers the viscosity of the solution and thus, may enhance the penetration of the bonding agent into the demineralized, collagen rich dentin surface; secondly, by lowering the surface tension of water, acetone has a 'water chasing' effect; and lastly, acetone is increasing the vapor pressure of water suggesting that it may enhance the removal of collagen surface water, which could then be exchanged for the acetone and ultimately for the adhesive resin[27]. Clinicians must be aware of the volatile characteristics and composition of adhesive systems to achieve effective bonding with one-bottle adhesive systems[20].

Hydroxyethylmethacrylate (HEMA) is a widely used monomer which also acts as a solvent and helps prevent hydrophilic and hydrophobic phase separations[28]. Some of the drawbacks include: HEMA retains water within the adhesive layer and adversely affects the mechanical strength[29], 70% of HEMA can be hydrolyzed in acidic solutions within a week at 37°C. HEMA provides low photopolymerization reactivity. Moreover, HEMA causes sensitized