Adhesive systems in restorative dentistry

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Abstract

Current adhesive systems have improved clinical procedures regarding both the evolution of components and their mechanism of action, and also regarding the reduction of the application operative time of each one of them, thus providing acceptable and predictable clinical efficacy. This demand for effectiveness has given rise to a variety of adhesive systems which, in many cases, are not used in dental practice. The aim of this paper is to review these adhesive systems to provide the necessary information and sequence of application so that dentists can properly select and use a given system according to each clinical situation.

Keywords: adhesion, biomaterials, operative dentistry.

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Introduction

Since 1955, with Buonocore's introduction of the concept of treating enamel to chemically change its surface and hence facilitate the adhesion of filling materials to enamel surfaces, adhesion dentistry has rapidly changed and evolved. This is so because adhesion is necessary to oppose and withstand contraction forces during the polymerization of composite resin, and to promote better retention and marginal seal when the restored tooth is in operation (2).

Nowadays, advances in biomaterials focus on improving their components, improving material performance, and simplifying techniques applied in clinical procedures to achieve better results in less time (3, 4).

Acid-etch adhesive systems can be used to achieve adhesion to dental structures. They can also be used to act as management and adhesive agents, as in the case of self-etch adhesives (5).

Acid-etching of the enamel surface gave rise to etch-and-rinse techniques, where both surfaces, enamel and dentin, are etched with acid. The acid is then removed so that the resin can adhere to the surfaces. Effective adhesion to dentin, at or above 17 MPa, has posed a much greater technological challenge than adhesion to enamel.

Spencer et al. (6) state that current dentin adhesion systems focus on the formation of a hybrid layer on the dentin surface, which has polymerized monomers within a collagen network of the dentin, hence resulting in micromechanical interlocking. With traditional etch-and-rinse systems, this infiltration technique requires the dentin surface to be wet to provide support to collagen fibers, hence allowing for the necessary resin penetration to create a mineral/collagen/resin interface (7).

Determining the moisture content of dentin can pose a challenge to restoration adhesion. An overly wet dentin surface may lead to emulsification and cause voids in the primer. Conversely, a desiccated dentin surface causes the collapse of collagen fiber, reduced resin penetration, and voids and gaps under the restorative material.

Following the permanent development of adhesive systems, they can be classified into two groups. The first group includes total-etch adhesive systems. These etch-and-rinse systems require an initial phase of tissue management with 37% phosphoric acid. This provides a porous and irregular surface which allows for the penetration of resin monomers to be polymerized, hence providing micromechanical retention through resin tags. This etching process eliminates the smear layer, which improves the interaction of the adhesive with the exposed collagen network, thus ensuring adhesive infiltration and the sealing of dentinal tubules (8).

Total-etch or etch-and-rinse techniques have been used for decades, with excellent verified clinical results on the enamel. However, results on dentin are more variable (9).

The second group includes self-etch adhesive systems. These systems, characterized by acid monomers that do not require rinsing, have become more popular given their technical simplicity, the need to follow fewer steps and because the professional does not need to determine residual dentin moisture (10). These systems etch, demineralize and infiltrate enamel and dentin simultaneously. The smear layer is impregnated but not eliminated, and rinsing is not indicated. Eliminating the etch-and-rinse step may reduce the risk of over-preparing the dentin, hence minimizing the problem of inadequate penetration of adhesive monomers and reducing the risk of postoperative sensitivity (11).

These self-etch systems have presented adequate and stable dentin bonding forces, even stronger than those of older adhesive systems (12).

The aim of this paper is to review these adhesive systems to provide the necessary information and clinical sequence of application so that dentists can properly select and use a given system according to each clinical situation.

Development

Adhesive systems are biomaterials which are crucial within aesthetic restoration clinical protocols (13). This is why the research into adhesion to different dental substrates has such a central role within dentistry studies. Its main aim is to find a system that complies with the three objectives of dental adhesion presented by Norling (14) in 2004:

- Preserving more dental structure.
- Achieving optimal and long-lasting retention.
- Preventing microfiltrations.

The first objective seems to have been achieved efficiently as the retention of adhesive restorations is possible on account of the micromechanical and chemical interlocking that takes place when etching the tissue, without affecting healthy dental tissue (15). However, the second and third objectives are the main areas to research within biomaterials and dental operative dentistry.

In their studies, Van Landuyt et al. (16) compare the performance of adhesives referred to as the "gold standard", called fourth-generation conventional etch-and-rinse adhesives given their excellent features and functionality in laboratory and clinical tests. In the various studies conducted, these adhesives have shown high bond-strength levels compared to sixth and seventh generation self-etch adhesives given the formation of water vesicles in the adhesive interface. This causes possible nanoleakage and restoration failure using self-etch systems.

Adhesive systems have evolved both regarding composition and action mechanisms on dental tissue, and also regarding their components and the number of clinical steps necessary for their application. This last aspect enables professionals to achieve lower technical sensitivity and an equivalent performance level on enamel and dentin. Adhesives can then be classified as follows (17):

1.- Three-step adhesives (Total-Etch Systems)

They require acid etching (enamel and dentin), rinse and dry, use of a priming agent and adhesive as steps to follow before placing the composite.

Once the tissues are demineralized, primers must transform the hydrophilic dental surface into hydrophobic surface, so that the bonding of adhesive resin is achieved. To do this, agents contain monomers that can be polymerized with hydrophilic properties, dissolved in acetone, water and/or ethanol. These agents carry monomers through the etched tissue (18).

Adhesive systems that have volatile organic compounds such as ethanol and acetone are based on their capacity to remove the remaining water. This makes it possible for the monomers to penetrate the microporosities caused by the acid etching on the enamel, within the open dentinal tubules and through the nano-spaces in the collagen network of the dentin. Hence full tissue infiltration would be achieved if such tissues have been previously wetted.

Water-soluble primers mainly have HEMA and polyalkenoic acid. The action mechanism of these materials is based on the fact that the water evaporates after application and the surface is air-dried, thus increasing HEMA concentration. The principle of different volatilities of the solvent and the solute is very important. Water has a much higher steam pressure than HEMA. This allows for its retention, as the solvent, water, evaporates at the drying stage.

The priming procedure ends with dispersion, using a light air stream to remove the solvent and leave a shiny and homogeneous layer on the surface. In the third step, the hydrophobic bonding agent is applied, which will chemically bond with the composite resin, applied afterwards.

One of the advantages of three-step systems is their capacity to achieve the necessary bond-strength to enamel and dentin. However, their main drawback is that the technique is very sensitive given the many clinical steps to follow for their application, and the risk of over-wetting or over-drying the dentin during rinsing and drying after the etching acid has been applied. These adhesives have reached bond-strength values of approximately 31 MPa (19, 20).

2.- Two-step adhesives

The adhesion mechanism of these systems is the same as that of their three-step predecessors, but they are more technique-sensitive.

These systems require the application of a wet adhesion technique as the priming step does not take place independently. The tissue must remain wet in the case of dentin to prevent the demineralized collagen from collapsing, thus preventing incomplete infiltration of the adhesive. However, it is very difficult for the clinician to reach the optimal degree of moisture, which is why this technique is operator-sensitive.

These systems have simplified the clinical technique, reducing, to some extent, working time. Two procedures are described:

- First, the primer and the adhesive come together in one package, and the acid etching agent comes separately. The main drawback of these systems is that the acid must be rinsed with water and then dried. However, the dentin must remain wet after acid etching, which is difficult to standardize clinically given the lack of stability of the demineralized matrix.
- Additionally, the primer now has monomers with acid groups that can act as the acid etching agent, and hence prepare the dental tissue for adhesion. The advantages of these systems are that the rinse stage is eliminated, and that the dentin surface is already prepared to receive the adhesive agent.

3.- Single-Step all-in-one Adhesives

These systems combine the three functions: acid etching, priming and adhesion in one stage. Their main advantage is that they are easy to apply and that it is not necessary to rinse the surface: only drying is necessary to uniformly spread the product before photopolymerization (21).

In these adhesive systems, the technique has been simplified, thus making it possible to keep hydrophilic acidic monomers, organic solvents and water in one solution. These components are essential to activate the process of dentin demineralization and the operation of the system (22). Solvents like acetone or alcohol are kept in the solution, but once dispensed, solvent evaporation begins. This evaporation triggers a separation phase, with the formation of multiple droplets and oxygen inhibition. There is also a lower degree of conversion, which promotes hydrolytic degradation, thus affecting the bonding capacity in the adhesive interface (23, 24). Van Meerbeek et al. (25) report bond-strength values of approximately 20 MPa.

Conclusion

The advances of contemporary restorative dentistry focus on the evolution of materials, the improvement of their components, and more simplified clinical techniques. This is done to achieve better results in less time.

A wide range of biomaterials is now available. The selection process is critical and fundamental to the clinician's job, so that patients are offered safe and reliable treatments that are highly aesthetic and meet their expectations.

Adhesive strategies are classified into two categories: a) acid etching and rinse systems, with complex components and adhesive procedures; and b) self-etch systems, which follow modern trends that favor more simplified clinical processes.

Finally, despite the efforts made by researchers and technological advances, the ideal adhesive technique and system, that is also durable and can be generally applied, has not been found yet. This can be attributed to many factors: biomaterials used, dental substrate and the professional in charge of the procedure.

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