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SHORT COMMUNICATION

Dentin Bonding Agents I: Complete Classification—A Review

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ABSTRACT

Traditional mechanical methods of retaining restorative materials have been replaced to a large extent by tooth conserving adhesive restorative techniques. Bonding techniques allow more conservative tooth preparation. Less reliance on macromechanical retention and less removal of unsupported enamel because adhesives have been evolving, so rapidly for the last few years, as the timing is right for evaluating the clinical status of present day adhesives. The purpose of this article is to provide a concise, comprehensive and updated classification of dentin bonding agents. Current products are highlighted to improve clinical use and performance of the materials.

Keywords: Conservative, Dentin bonding agents, Classification, Current products.

INTRODUCTION

The principles of adhesive dentistry date back to 1955 when Buonocore, after observing the industrial use of phosphoric acid to improve adhesion of paints and resin coatings to metal surfaces, applied acid to the teeth to 'render the tooth surface more receptive to adhesion'. Buonocore's pioneering work led to major changes in the practice of dentistry. Today, we are all in the age of adhesive dentistry.[1]

Bonding techniques allow more conservative tooth preparation. Less reliance on macromechanical retention and less removal of unsupported enamel.

The availability of new scientific information on the etiology, diagnosis and treatment of carious lesions as well as the introduction of reliable adhesive restorative materials has subsequently reduced the need for extensive tooth preparation.[1]

The 1st dental adhesive bonded resins to enamel only with little or no dentin adhesion or sealing of dentin margins. Subsequent generations of dental adhesives have dramatically improved the bond strength to dentin and the sealing of dentin margins while retaining a strong bond to enamel. The use of dental resins as cements as well as direct or indirect restorations will continue to increase as the use of metals in dentistry decreases and patients demand more esthetic procedures.

CLASSIFICATION OF DENTIN BONDING AGENTS

The bonding agents are classified as follows:

1. According to generations
2. Based on mode of application
3. Based on number of steps
4. Based on etching pattern.

CLASSIFICATION BASED ON GENERATIONS

First-Generation Adhesives (1960)

- Development of surface-active comonomer NPG-GMA
- Theoretically, this comonomer could chelate with calcium on the tooth surface to generate water-resistant chemical bonds of resins to dentinal calcium
- *Bond strength* 2 to 3 MPa.

  Drawbacks
- It showed poor clinical results
- *Example*: Cervident (SS white), cosmic bond.[1,2]

Second-Generation Adhesives (Late 1970s)

- Phosphate ester dentin bonding agents were introduced containing phenyl P and HEMA in ethanol
- Its mechanism of action was based on the polar interaction between negatively changed phosphate groups in resin and positively changed Ca^{++} in smear layer
- The bond strength was 5 to 6 MPa.

Drawbacks

- Loosely attached smear layer and hydrophobic nature
- *Example*: ScotchBond (3M dental), Clearfil bond system.

Third-Generation Adhesives (1980s)

- The third generation materials were designed not to remove the entire smear layer but rather to modify it and allow penetration of acidic monomers, such as phenyl-P and Penta
- These introduced acid-etching to heavily alter or to remove the smear layer and demineralizing dentin and a separate primer (bifunctional monomer in a volatile solvent) designed

to penetrate dentin by its own monomer and those of adhesive monomers
- Adhesive is an unfilled or partially filled resin that may contain some component of primer (e.g. HEMA) in an attempt to promote increased bond strength
- Bond strength is 3 to 8 MPa
- *Examples*: ScotchBond 2, Tenure, Universal bond 2, Coltene ART.

Fourth-Generation (Early 1990s)

- When primer and bonding resin are applied to etched dentin, they penetrate the intertubular dentin forming a resin dentin interdiffusion zone or hybrid layer
- They have the ability to bond as strongly to dentin as to enamel (total etch)
- Ability to bond to moist dentin (wet bonding)
- Multiple substrate bonding to metal, amalgam, porcelain and indirect composite
- Bond strength 13 to 30 MPa
- *Examples*: All-Bond 2, OptiBond FL and ScotchBond multipurpose.

Fifth-Generation Adhesives

These are essentially distinguished by being 'one-step' or 'one-bottle' system. This is a bit of a misnomer because these products are applied in two steps (etchant + primer and adhesive) in one bottle.
- Bond strength is 3 to 25 MPa.

DRAWBACKS

- They lack many of the components necessary to perform multisubstrate bonding
- Multiple coats of these agents are required
- *Examples*: Prime and bond, single bond, OptiBond Solo and OptiBond Solo Plus.[1,2]

Sixth-Generation Adhesives

It was introduced in late 1990 and early 2005:
1. They dissolve the smear layer when applied and do not require rinsing.
2. Minimize postoperative sensitivity as they do not expose dentinal tubules.
3. Bond strength to enamel and superficial dentin are typically greater than deep dentin.

Type I	*Type II*
1. Self-etching primer and adhesive	1. Self-etching adhesives
2. Have components liquid 1-acidic primer liquid-2-adhesive that are separately to the tooth	2. Two bottles or unit dose containing acidic primer and adhesive are first mixed and then applied
3. Are generally compatible with self-cured composite	3. Are not compatible with self-cured composite
4. Example: Clearfil SE bond, adhese	4. Example: Xeno-III Adper Prompt LPOP one-up bond

The bond strength to dentin and enamel is lower than the fourth- and fifth- generation systems.[3]

Seventh-Generation

Introduced in Late 2002

- Self-etching adhesive
- Require no mixing
- Not compatible with self-cured composite cores or resin cements
- Single bottle containing acidic adhesive
- Examples—iBond
- Bond strengths and marginal sealing to be equal to the sixth-generation system.

Eighth-Generation

- Dual-cured self-etch adhesive for direct and indirect restorations with self-, light- and dual-cured resin materials.[13,15,16]

CLASSIFICATION-BASED MODE OF APPLICATION[4]

On the basis of their clinical approach to the smear layer modern dentin adhesive systems can also be classified as follows . Based on this criteria, there are following mechanisms of adhesions:
1. Adhesives which modify the smear layer[5] and incorporate it into the bonding process. They require one or two steps. They use a single adhesive or primer and adhesive. *Examples*:

One step	*Two steps*
Prime and Bond 2.1	Optec Universal Bond

2. Adhesives which completely remove the smear layer are subdivided into two and three step application. A two-step process involves dentin conditioning followed by combined primer and adhesive whereas a three-step process involves separate conditioning priming and bonding application.

Multiple bottle	*One bottle*
Examples: All-Bond 2, Scotchbond multipurpose	Examples: OptiBond SOLO, One step

3. Adhesives which dissolve the smear layer, rather than remove it. The process is accomplished in two steps using a combined conditioner and primer (self-etching primer) followed by application of adhesive resin.
   Advantage: 1 no. rinsing: Quick application
4. Less postoperative sensitivity than total etch.[9]

CLASSIFICATION BASED ON NUMBER OF STEPS[6]

Generation	*Steps*	*Description*
1st	3	Etch enamel, apply adhesive
2nd	3	Etch enamel, apply adhesive
3rd	3	Etch enamel, apply primer
4th	2	Total etch, apply primer
5th	2	Total etch apply adhesive
6th	1 or 2	Apply self-etch adhesive
7th	1	Apply self-etch adhesive

CLASSIFICATION BASED ON ETCHING PATTERN[7]

The bonding agents were earlier divided into generations by Dr Marcos Vargas. With the advent of self-etching primer systems, the generational classification ceased to exist. It was officially withdrawn by its introducer during the 5th Indiana Conference held at University Center in June, 2000.

It was then accepted that based on their application method, the bonding agents could either be total-etch or self-etch.

TOTAL ETCHING TECHNIQUE

The concept of total etching is the simultaneous etching of enamel and dentin.

Total etching technique may either be as follows:[8]

- Multibottle (fourth-generation, examples: All-Bond 2, multipurpose ScotchBond)
- One bottle (fifth-generation, examples: Prime and Bond NT, single bond).

SELF-ETCH SYSTEM

In this method, there is no separate etching and rinsing. This approach (i) lessens clinical application time; (ii) reduces technique sensitivity. The residual smear layer remnants remain within the bond.

A self-etch approach involves either a two or one-step application procedure. These can be divided into (i) self-etching primer, (ii) self-etching adhesives.

All-in-One Self-etching Adhesive Systems

'All-in-one' dental adhesive systems which fall into the family of self-etching adhesive materials. The same solution serves as conditioner, primer and adhesive.

'All-in-one' adhesives are now increasingly used in pediatric dentistry. The hybridization that these self-etching materials create in primary dentin is consistent with and similar to the hybridization provided by total etch dentin adhesives.[9,10]

Examples: G-Bond (GC America), iBond (Heraeus Kulzer).

Depending on etching aggressiveness, the self-etch systems are divided into strong, mild and intermediate strong adhesives.

Strong Self-etch Adhesives

Have pH of 1 or below. The underlying bonding mechanism is primarily diffusion based, similar to etch and rinse approach. They have low bond strength values due to (i) high initial acidity, (ii) residual solvent (water) remaining within the adhesive interface.

Mild Self-etch Adhesives

Have pH of around 2. They demineralize the dentin only to a depth of 1 μm keeping residual hydroxyapatite attached to collagen. Weakest property is their bonding potential to enamel.

Intermediate Strong Self-etch Adhesives

Have pH of about 1.5. They may be (i) two step, e.g. OptiBond Solo Plus; (ii) single step, e.g. Xeno IV (Dentsply Cault), iBond (Heraeus Kulzer), G-Bond (GC America).

A comparison of the mean alpha score percentages revealed no difference between the etch-and-rinse, self-etch primer and self-etch-adhesive categories of bonding systems except for marginal adaptation where etch-and-rinse was found to be superior to SEA.[11,15]

Self-etching primers incorporate a significant amount of water as a solvent in order to promote the ionization of the acidic monomers. After solvent evaporation, the adhesive layer can be very thin and therefore the mechanical properties may be low. In addition, a demineralized dentin zone has been found below the hybrid layer formed by self-etching primers, which is not fully protected by the adhesive and this could jeopardize bond strength.[12]

The increase in bond strength obtained by increasing the number of consecutive coating of adhesives (up to three coats of total-etch and two coats of self-etch) suggests that this technique might be useful in all total-etch and self-etch systems.[14]

CONCLUSION

Adhesive dentistry has revolutionized restorative dental practice during the past 30 years. Today, we all are in the age of adhesive dentistry. Improved adhesive materials have made resin-based composite restorations more reliable and long standing. As we enter the new millennium, it is important to examine the past keeping abreast of the fast rapidly spreading advances in the practice of adhesive dentistry with the latest trends.

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