REVIEW ARTICLE

BONDING SYSTEMS - PRESENT AND FUTURE

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ABSTRACT

There have been great advances in knowledge about bonding to dentin during the past decade. From the total etch three step bonding to current no etch one step bonding, adhesive dentistry has evolved. The development of self-etching primer adhesive systems has greatly simplified resin bonding but the simplification of bonding steps has not improved the quality or the durability of resin–dentin bonds. This article aims to give an insight on the newer generation of bonding systems.

Keywords : *Bonding, Etch, Dentin.*

INTRODUCTION

Dental bonding systems have evolved in the past 45 years, with variations in chemistry, application, mechanism, technique, and effectiveness. The evolution was accompanied by the development of improved esthetic dental materials, like composite resin and ceramic, and an increasing demand by patients for esthetic dentistry. As the demand for bonded esthetic restorations has increased, the evolution of bonding agents accelerated. Variations in the number of bottles and the mechanism of bonding have defined each "generation" of bonding systems. The latest generations of bonding agents have reduced steps and components, having the etchant, primer and adhesive in a single bottle, making it the "All-in-one" bonding system. This article aims to discuss the latest generation bonding agents with respect to their properties, advantages and disadvantages and the future of these systems.

EVOLUTION OF THE BONDING SYSTEM

In 1960's and 70's came the first and second generation bonding agents which did not recommend dentin etching and relied on adhesion to smear layer. Hence, they had weak bond strength. In 1980's came the third generation of bonding agents which etched the dentin, had a separate primer thus increasing the bond strength .Fourth generation systems were introduced in 1990's having the etchant, primer and adhesive in separate bottles which gave very good bond strengths but were extremely technique sensitive .These were followed by the fifth generation systems which combined the primer and adhesive in one bottle, reducing the number of application steps to 2. Around the turn of this century, self-etching primers were introduced, which were termed as the sixth generation of bonding agents. These systems combined the etching, priming and bonding but it still was a two bottle system. Some systems had to be mixed outside the tooth in a well while others were mixed inside the tooth.

The so called Seventh-Generation was introduced in late 2002 and combines the acid, primer, and resin in one bottle. These materials involve only a single step, which eliminates separate etching, rinsing, and mixing, eliminating all additional steps needed in the previous generations claiming to reduce the technique sensitivity.[1] Was there any need for this newer generation of bonding agents? The answer would be yes as

1. Post-operative sensitivity still a major problem.
2. 4th and 5th generation use the phenomenon of moist bonding introduced by Kanca and Gwinnet et al in 1990's[2] Proper degree of wetness is hard for dentist to visually access and hard for manufacturer to explain. And the debate of how wet is wet? And how dry is dry?
3. Over etching of the dentin results in nano-leakage when the demineralized dentin is too thick to be fully penetrated by the adhesive resins within the given time.
4. 6th generation must be sequentially applied or mixed properly to work efficiently, and they required multiple bottles.

MECHANISM OF BONDING

The fourth and the fifth generation s of bonding systems were based on the concept of 'total etch' wherein the smear layer was completely removed from the dentin

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and the demineralised dentin formed a 'Hybrid layer' or 'Resin dentin inter diffusion layer' with the bonding agent. The Sixth and Seventh-generation bonding agents use the smear layer as a bonding substrate. The acidic primer demineralizes the smear layer and the top layer of the underlying dentin surface. The acidic primer also infiltrates the exposed collagen along with the hydrophilic monomers which then copolymerize. Because the etched surface is not rinsed, the demineralized smear layer is incorporated into the hybrid layer.[3,4] For the total etch technique the hybrid layer ranges in thickness from 3-5µm, and for the sixth and seventh generation bonding systems this layer ranged from .0.5 um to 2 um, depending on the pH of the acidic monomer.[5]

In 2003, depending on the pH, Van Meerbeck et al[6] classified the acidic monomer, into-

- Mild pH 2, hybrid layer is 1-2µm in size (Clearfill S3, GBond)
- Intermediate pH 1.5, hybrid layer is 2-3µm in size (AdheSE, iBond)
- Strong pH 1, hybrid layer is 3-5µm in size (Prompt L pop 2)

Hence, the more acidic the primer, deeper is the mineralization.[7,8,9,10] The acidic primer and adhesive monomers infiltrate collagen fibres together as the primer decalcifies the inorganic component in dentin to the same depth, this should minimize voids, potential leakage, postoperative sensitivity by decreasing the hydraulic conductance and nano-leakage resulting from an insufficient penetration depth of the adhesive[11]

The etching ability of these self-etching agents is questionable. So, whenever unground enamel is present should it be etched with phosphoric acid before the use of a seventh-generation bonding agent? The problem with pre-etching the enamel with phosphoric acid is that the washing process tends to cause a diluted acid to contact the dentin. This then may result in a partial decalcification of the dentin to depths greater than the extent to which the self-etching bonding agent will penetrate. An alternative to application of phosphoric acid to unground enamel is pumicing of the enamel. This technique provides a similar bond strength to that found with etching with phosphoric acid.[12,13]

Advantages and Disadvantages of the One Step Bonding Agent

- One-step procedure, no mixing or rinsing the tooth
- Delivery option, single bottle or unit-dose
- Less postoperative sensitivity.
- The shallow etch ensures good resin infiltration.
- Tolerant to moist or dry environments - Most seventh generation bonding agents have water as a solvent. Thus, the wetness or dryness of the tooth surface is less critical than it is with bonding agents with solvents containing ethanol or acetone.
- Available in light-cured and dual-cured formulations Light-cured seventh generation bonding agents are not compatible with dual- and self-cured composite cores and resin cements.

The dual-cured seventh-generation bonding agents (Clearfil DC BOND, Futurabond DC, Xeno IV DC) solve this problem. Ideal bonding agent is still a future and hence it has few disadvantages too-

- Less effective bonding of enamel
- Immediate bond strength (24MPa) is in the same range as the previous generations but the initial bond might deteriorate with aging, which could lead to premature failures.
- Bond strength to cut enamel-20 MPa, superficial dentin-25 MPa and deep dentin-18 MPa.

This can be attributed to the acidic, hydrophilic and hydrophobic monomers, organic solvents and water placed together in one bottle which affects the efficiency of the individual component. As the concentration of hydrophobic crosslinking monomer is reduced, the strength is also reduced. The prescence of acid in the same bottle as the bonding components results in two types of degradation reactions.

Firstly the reactive solvent molecule can add at the polymerizable group, which results in loss of polymerizable function. Secondly, reaction of water with the polymerizable group doesn't destroy its function but separates the group from rest of the monomer by hydrolysis.

The above degradation reaction[14] leads to decreased density of the polymerizable group. The acidic components produced by hydrolysis are not polymerized into the network thus etching of the dentin further. There is also a problem of chemical degradation of the adhesive which may occur at high temperatures; so long term storage requires refrigeration like for GBond 1-28ÚC, Clearfill S3 Bond 2-8ÚC, iBond <8ÚC, Xeno IV 2-8ÚC, 3M ESPE Adper 2-8ÚC, Xeno V >24ÚC.

To solve this problem acrylic amide resins have been used in few products like Xeno V and AdheSE One instead of acrylic esters. They are less prone to hydrolysis. Tertiary butanol instead of ethanol as solvent doesn't react with acrylate resins in the same way as ethanol does. Hence, the solvent type should also be taken into account when choosing the adhesive system.

It has been found that the shear bond strength of acetone based one step adhesive is lower than that of ethanol based adhesives due to the water chaser effect of acetone.[15]

Other problems with these bonding agents are-

- Bonding to sclerotic and caries affected dentin might be problematic.[16]
- Shear bond strengths of different bonding systems may also be affected by dentin depth, orientation of the tubule, but not by location of the dentin (occlusal or cervical).[17]
- Insufficient long term research.
- Light cured seventh generation bonding agents cannot be used with dual cure or self cured composites and resin cements chemical-cured composites that utilize tertiary amine as a component of the catalyst. This is because the acidic monomers deactivate the more basic amines
- May inhibit set of self-cure or dual cure resin materials.

Both single-bottle total-etch adhesives and single-step self-etch adhesives are utilized without an additional bonding resin layer. In these adhesives, the oxygen-inhibited layer contains acidic monomers that come into direct contact with the chemical-cured composite where they can titrate the basic amine accelerators and inactivate them. Clinically, this may result in the debonding of core buildups with self- or dual-cured composites during impression taking This has largely been rectified in many single-bottle adhesives by the introduction of dual-cured versions that include an additional bottle of chemical co-initiator containing sodium benzene sulphinate. However, the use of a chemical co-initiator improves its tensile bond strength with selfor dual-cured composites only to a certain extent. Another question is are self-etch-adhesives too hydrophilic? The single-step self-etch adhesives having hydrophilic resin systems attract water. It is difficult to evaporate water from these adhesives, and even if evaporation is successful, water will rapidly diffuse back from the bonded dentin into the adhesive resin. Thus it behaves as permeable membranes after polymerization.[18] During this period, water will diffuse through the adhesive layer and is trapped in the form of water blisters along the adhesive-composite interface, with thehydrophobic resin composite taking an impression of these transudated water droplets. Such a process is commonly known to the resin-coating industry and is termed "osmotic blistering". It has also been suggested that the osmotic gradient that is responsible for the induction of this type of water transport is derived from the dissolved ions that resided within the oxygen inhibition layer of these polymerized adhesives.

The more easily recognized pattern is in the form of fractal-like, water channels that originate from the surface of the hybrid layer, and extend through the adhesive layer to reach the adhesive-composite interface. These water channels have been given the term "water trees"[19]. Hydrophobic HEMA-free self etching agents such as GBond were prone to phase separation, while HEMA-containing hydrophilic Self etching agents, such as Clearfil S3 Bond and Xeno III were predisposed to forming osmosis-induced droplets. Hybrid bond, Absolute, and iBond featured both phase separation as well as osmosis. Optibond, All-in-one exhibited a clustering reaction of the filler particles upon solvent evaporation. From a clinical perspective, as the diffusion of dentinal fluid across the adhesives occurs relatively slowly, it is unlikely to result in severe post-operative sensitivity.

CONCLUSION

Use of seventh generation bonding agents has made adhesive dentistry more easy and predictable for the practitioner. Clinically, they can be used with direct light cured resin restoration, indirect resin restoration, core build up and ceramic veneers, inlays & onlays. They can be used on bur cut dentin and enamel but when uncut enamel is present, it needs to be prepared. Manufacturer's instruction and adequate isolation are still one of the key factors responsible for achieving predictable results. To ensure success long term research on the efficacy of these bonding agents is required along with improvements in the chemistry to overcome the present disadvantages.

REFERENCES

1. **Sano H, Shono T, Takatsu T,Hosoda H.** Microporous dentin zone beneath resin-impregnated layer. Oper Dent 1994; 19:59–64Pahlavan A, Dennison JB, Charbeneau GT. Penetration of restorative resins into acid-etched human enamel. J Am Dent Assoc 1976; 93:1170–1176
2. **John Kanca III.** Resin bonding to wet substrate . I . Bonding to dentin.Quintessence Int 1992; 23 : 39-41
3. **Gordan VV,Vargas MA, Denehy GE.** Interfacial ultrastructure of the resin–enamel region of three adhesive systems. Am J Dent 1998; 11:13–16
4. **Perdigao J.** Dentin bonding as a function of dentin structure. Dent Clin North Am 2002;46:277–301
5. **Tay FR, Pashley DH.** Aggressiveness of contemporary self-etching systems. I: Depth of penetration beyond dentin smear layers. Dent Mater 2001; 17: 296–308
6. **B Van Meerbeck, J De Munck, Y Yoshida, S Inoue, M Vargas, P Vijay, K Van Landuyt, P Lambrechts, G Vanherle.** Adhesion to enamel and dentin: Current status

and Future Challenges. Oper Dentistry 2003; 28-3:215-235

7. **Tay FR, Pashley DH, Peters MC.** Adhesive permeability affects composite coupling to dentin treated with a self-etch adhesive. Oper Dent 2003; 28: 612–623

8. **Tay F, Sano H, Carvalho R, Pashley E, Pashley D.** An ultrastructural study of the influence of acidity of self-etching primers and smear layer thickness on bonding to intact dentin.J Adhes Dent 2000; 2:83–98

9. **Tay F, Pashley D.** Permeability of single-step, self-etch adhesives: the cost of saving time.Tokyo, 2001,23– 39

10. **Chersoni S, Suppa P, Grandini S, Goracci C,Monticelli F,Yiu C, Huang C, Prati C, Breschi L,Ferrari M, Pashley DH, Tay FR.** In vivo and in vitro permeability of one-step selfetch adhesives J Dent Res 2004; 83:459–464

11. **Tay F, Pashley D,Yoshiyama M.** Two modes of nanoleakage expression in single-step adhesives.J Dent Res 2002; 81:472–476

12. **Pioch T, Staehle HJ,Wurst M, Duschner H, Dorfer C.** The nanoleakage phenomenon: influence of moist vs dry bonding. J Adhes Dent 2002; 4:23–30

13. **Kanemura N, Sano H, Tagami J.** Tensile bond strength to and SEM evaluation of ground and intact enamel surfaces. J Dent 1999; 27:523–530

14. **Nishiyama N, Suzuki K, Yoshida H, Teshima H, Nemoto K.** Hydrolytic stability of methacrylamide in acidic aqueous solution. Biomaterials. 2004;25:965–969

15. **Guilherme Carpena Lopes, Paula C. Cardoso,Luiz Clovis Cardoso Vieira, Luiz N. Baratieri, Karina Rampinelli, Gisele Costa.** Shear bond strength of acetone-based one-bottle adhesive systems. Braz. Dent. J 2006; 17

16. **Solen Karakaya, Nimet Unlu, Esra Can Say, Fusun Ozer, Mubin Soyman, Junji Tagami.** Bond Strengths of Three Different Dentin Adhesive Systems to Sclerotic Dentin. Dent Mater J 2008; 27: 471ÿ 479

17. **Sattabanasuk V, Shimada Y, Tagami J.** The bond of resin to different dentin surface characteristics.Oper Dent 2004;29 :333-41

18. **Tay F, Pashley D, Suh B, Carvalho R, Itthagarun A.** Single-step adhesives are permeable membranes.J Dent 2002; 30:371–82

19. **Tay F, Pashley D.** Water treeing: a potential mechanism for degradation of dentin adhesives.Am J Dent 2003; 16:6–12