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Self etching system v/s conventional bonding: Advantages, disadvantages

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Abstract
Adhesive dentistry has revolutionized the paradigm of esthetic dentistry. In the past few years, adhesive dentistry has withdrawn much attention due to constant changing concepts and research. In the light of inherent drawback of high technique sensitivity associated with total etch technique, Self etch systems were developed. Although, self etching systems have shown excellent results for some type of restorations, their use for universal application in routine practice of minimally invasive dentistry is limited. Concurrently, a dilemma has arisen as to whether the total etch adhesives are still the benchmark for dental adhesives or the newer self etch systems offer an improvement over the past. This article aims to review the current concepts and controversies in adhesive systems.

Keywords: Self-etch v/s conventional bonding, generations of bonding agents

Introduction
Buonocore [1], in 1955 postulated that acid could be used before application of resins for surface treatment. This marks the start of adhesive dentistry. Later Fusayama [2] *et al*. explored the possibility of acid etching dentin. This in turn opened the door and Nakabayashi *et al*. discovered the hybrid layer. These concepts are still used in adhesive systems and have been currently used for aesthetic restorations, prosthodontics, orthodontics and endodontics.
Several systems of classification have been proposed. What distinguishes the several classes of adhesives are the modes of application of the solutions and, within classes, the components and chemistry inherent to a particular material. In a true sense, only two kinds of adhesive systems exist: An Etch and rinse/Total etch system or a No rinse/Self etch system. The former is either a three or a two steps system, where in a separate acid etching step is always required for smear layer removal. On the other hand, the self-etch adhesives can either involve two or one step applications. The first application demineralizes and primes the tooth surface simultaneously. The adhesive layer is applied as a second step. One-step bonding materials demineralize, prime and bond in a single step application. The aim of adhesive technique irrespective of whether a total etch technique or a self-etch is used, is to obtain a well bonded structure, with minimal micro leakage and absent post-operative sensitivity. Restorations must be able to maintain stability under temperature variation and mechanical stress, the condition ubiquitous in oral environment. Adhesive systems should be nontoxic, provide adequate bond strength, resist wear and water sorption.
Self-etching system offers high durability when bonded to dentin. On the other hand, total-etching system provides higher bond strength when bonded to uncut enamel and excellent marginal integrity (Fewer marginal defects and less marginal discoloration) as required in orthodontics.

History of adhesive systems
Adhesives over the years
- **First and Second Generation:** 1960-70
  No acid etching, Adhesion to smear layer, Weak bond strength.
- **Third Generation:** 1980
  Acid etching, Separate Primer, Increased Bond Strength, Marginal Staining.

- **Fourth Generation:** 1990
  Hybrid layer of dentin & collagen, Dentin seal, Wet bonding concept.
- **Fifth Generation:** mid 1990
  Combined primer & adhesive, High bond strength, Unit dose packaging.
- **Sixth Generation:** 2000
- Self etching primers, Reduced post-operative sensitivity, Bond strengths lower than fourth & fifth generations.
- **Seventh Generation:** 2002
  All in one, Good bond strength & marginal sealing.

The concept of self-etching approach was created approximately 20-30 years ago. Though the first and second generations of bonding agents can be considered self-etch materials because no acid etching/rinsing or conditioning step were used.

The basic composition of self-etch primers and self-etch adhesive system is an aqueous solution of acidic functional monomers, with a pH relatively higher than that of phosphoric acid etchants. The role of water is to provide the medium for ionization and action of these acidic resin monomers. Because self-etch adhesive systems do not require a separate acid conditioning step and moist post-rinse control, they are considered simplified adhesive materials. They offer some advantages over conventional etch-and rinse systems, such as reduction of postoperative sensitivity and less technique sensitive. Another advantage is that infiltration of adhesive resin tends to occur simultaneously with the self-etch process.

The demand for reduced technique sensitivity, shorter clinical application time and less incidence of post-operative sensitivity have made self-etch adhesive systems a promising approach when compared to the etch-and-rinse systems [3-11].

The current self-etch adhesive systems are classified based on the number of clinical application steps: one step or two-step adhesives [5]. Two-step self-etch adhesive systems include the use of a hydrophilic etching primer, which combines acidic monomers that simultaneously etch and prime tooth substrate [12, 13], and after solvent evaporation, a layer of hydrophobic and bonding agent seals the dentin [8].

One-step self-etch adhesive systems are all-in-one adhesives, which combine the etching, priming and bonding [14] thus containing acidic functional monomers, hydrophilic and hydrophobic monomers, water and organic solvents into a single solution [15].

The bonding mechanism of self-etch adhesive systems has been intensely investigated and two-fold bonding mechanisms; micro-mechanical interlocking and chemical bonding were described, which seems to be advantageous in terms of restoration durability. The micro-mechanical bonding contributes to provide strength against mechanical stress, while the chemical interaction reduces hydrolytic degradation, keeping the marginal sealing of restorations for a longer period [4, 5, 14, 16]. The functional acidic monomers are able to chemically interact with hydroxyapatite and are composed by specific carboxylic, phosphonic or phosphate groups.

Total etch vs. self etch: Evidence based dentistry

Bonding to enamel

Bond strength is the measure of load bearing capacity of the adhesive. It has been suggested bond strengths of 17 MPa to 20 MPa are required to resist contraction forces sufficiently to attain gap-free margins of resin composite restorations. A minimum bond strength of 8 to10 MPa is reported to be adequate for most clinical orthodontic needs.

The enamel bond strengths of earliest self-etch adhesives were lower than etch and rinse adhesives. Nevertheless, roughening of enamel to remove prismless enamel improves the enamel bonding ability of self-etch adhesives. A separate 'phosphoric acid enamel etching' step improves bonding of self-etch adhesives to enamel. Two step self-etch adhesives bond at an acceptable level to ground enamel in vitro but not as well to the intact enamel.

Classification by generation

The concept to classify by generation was used because of the complexity of bonding agents, the variety of classifications refers to what order type of adhesive was developed by the dental industry. Adhesive dentistry began in 1955 by Buonocore on the benefits of acid-etching. With changing technologies, dental adhesives have evolved from no-etch to total-etch (4th and 5th generation) to self-etch (6th, 7th and 8th generation) systems [17]. Each generation has attempted to reduce the number of bottles involved in the process, to minimize the number of procedural steps, to provide faster application techniques and to offer improved chemistry to facilitate stronger bonding.

First generation

The first-generation bonding systems were published by Buonocore in 1956 [18]. These bonding agents were designed for ionic bonding to hydroxyapatite or for covalent bonding (hydrogen bonding) to collagen. However, immersion in water would greatly reduce this bond. After nine years, Bowen used a coupling agent to overcome this problem [19]. He addressed this issue using that acted as NPG-GMA a primer or adhesion promoter between enamel/dentin and resin materials by chelating with surface calcium, where one end would bond to dentin, and other would polymerize with composite resin [19]. Overall, this generation leads to very poor clinical results as well as low bond strength in the 1-3 MPa range [20].

Second generation

The second generation of dentin bonding agents were introduced in the late 1970s, and sought to improve the coupling agents that were utilized in the first generation of adhesives. The 2nd generation of dentin adhesives primarily used polymerizable phosphates added to bis-GMA resins to promote bonding to the calcium in mineralized tooth structure [20, 21].

Bonding mechanism involves formation of ionic bond between calcium and chlorophosphate groups. This ionic bond would rapidly degrade in water submersion (again analogous to saliva) and even the water within the dentin itself, and cause debonding and/or microleakage [20]. The smear layer was still not removed, and this contributed to the relatively weak and unreliable bond strengths of this second generation [20]. The smear layer is really a smooth layer of inorganic debris that remains on the prepared dentin surface as a result of tooth preparation with rotary instruments (the drill). This generation of bonding agents is no longer used, due mainly to failed attempts to bond with a loosely bond smear layer. Bond strength: 4-6 Mpa [22].

Third generation

In the late 1970s and early 1980s, third generation dentin bonding agents were presented. The third-generation bonding systems introduced a very important change: the acid etching

of the dentin in an effort to modify or partially remove the smear layer [20]. This opened the dentin tubules and allowed a primer to be placed after the acid was completely rinsed away. While this method achieved a greater bond, it was considered controversial in dentistry as the feeling existed that dentin ought not to be etched. After the primer was added, an unfilled resin was placed on both dentin and enamel. The weak link with this generation was the unfilled resins that simply did not penetrate the smear layer effectively according to Tao *et al*. in 1988 [23].

Fourth generation

In 1980s and 1990s, fourth generation dentin bonding agents were introduced. The fourth-generation materials were the first to achieve complete removal of smear layer [20] and still considered as the golden, standard in dentin bonding. In this generation, the three primary components (etchant, primer and bonding) are typically packaged in separate containers and applied sequentially. The concept of total-etch technique and moist dentinal hallmarks of the 4th generation systems [20, 24] where dentin and enamel are etched at the same time with phosphoric acid (H3PO3) for a period of 15-20 s [25]. However, the surface must be left moist "wet bonding", in order to avoid collagen collapse. The application of a hydrophilic primer solution can infiltrate the exposed collagen network forming the hybrid layer [20, 26]. The hybrid layer is formed by the resin infiltrated surface layer on dentin and enamel. The goal of ideal hybridization is to give high bond strengths and a dentin seal [27]. Bond strengths for these adhesives were in the low- to mid-20 MPa range and significantly reduced margin leakage compared to earlier systems [1]. This system was very technique sensitive and required an exacting technique of controlled etching with acid on enamel and dentin, followed by two or more components on both enamel and dentin. These systems are very effective when used correctly, have good long-term clinical track record, and are the most versatile of all the adhesive categories, because they can be used for virtually any bonding protocol (direct, indirect, self-cure, dual-cure or lightcure). These systems are still the standards by which the newer systems are judged. However, these systems can be very confusing and time consuming with so many bottles and application steps. Because of the complexity of multiple bottles and steps, dentists began requesting a simplified adhesive system.

Fifth generation

In the 1990s and in the ongoing decade, the fifth-generation bonding systems sought to simplified the process of fourth generation adhesion by reducing the clinical steps which results in reduced working time. These are distinguished by being "one step" or "one bottle" system. In addition, an improved way was needed to prevent collagen collapse of demineralized dentin and to minimize if not totally eliminate, postoperative sensitivity [14, 20, 28]. So, the most common method of simplification is "one bottle system" combined the primer and adhesive into one solution to be applied on enamel and dentin simultaneously with 35 to 37% phosphoric acid for 15-20s. This single bottle, etch-and-rinse adhesive type shows the same mechanical interlocking with etched dentin occurs by means of resin tags, adhesive lateral branches and hybrid layer formation and shows high bond strength values to dentin with marginal seal in enamel [26]. These kinds of adhesives systems may be more susceptible to water degradation over time than the fourth generation. This is because the polymerized primer of the "one bottle system" tends to be hydrophilic in nature. However, when using the fourth generation, the hydrophilic primer is covered by a more hydrophobic resin, making it less susceptible to water sorption. Not all 5th generation adhesives are compatible with dual and self-cured or core materials. The lower PH of the Oxygen-inhibited layer, or the monomers in some simplified products, are too acidic and thereby de-activate the tertiary amine in chemical-cured composites. As well as the same in regards to the number of applications (unfilled need more applications), so it is critical to follow the manufacturer's directions. Several long-term studies indicate that 5th generation dental adhesive achieve high clinical bond strengths. In addition, the resin-dentin bond is prone to water degradation, 5th generation adhesives are more prone to water degradation than 4th generation dental adhesive. Representative dentin bond strength is 3 to 25 MPa.

Sixth generation

The sixth generation bonding systems introduced in the latter part of the 1990s and the early 2000s also known as the "self-etching primers", were a dramatic leap forward in technology. The sixth generation bonding systems sought to eliminate the etching step, or to include it chemically in one of the other steps: (self-etching primer + adhesive) acidic primer applied to tooth first, followed by adhesive or (self-etching adhesive) two bottles or unit dose containing acidic primer and adhesive; a drop of each liquid is mixed and applied to the tooth. It is recommended that the components are mixed together immediately before use. The mixture of hydrophilic and hydrophobic resin components is then applied to the tooth substrate [29]. Evidently, these bonding systems are characterized by the possibility of achieving a proper bond to enamel and dentin using only one solution [20]. The biggest advantage of the sixth generation is that their efficacy appears to be less dependent on the hydration state of the dentin than the total-etch systems [26]. Unfortunately, the first evaluations of these new systems showed a sufficient bond to conditioned dentin while the bond with enamel was less effective. This may be due to the fact that the sixth generation systems are composed of an acidic solution that cannot be kept in place, must be refreshed continuously and have a pH that is not enough to properly etch enamel [30]. In order to overcome this problem, it is recommended to etch enamel first with the traditional phosphoric acid prior to using it. However, those utilizing this technique should take care to confine the phosphoric acid solely to the enamel. Additional etching of the dentin with phosphoric acid could create an "over-etch" situation where the demineralization zone is too deep for subsequently placed primers to completely penetrate [26]. While data indicates that 6th generation adhesives will adhere well to dentin (41 MPa at 24 hours), the bond to enamel is at least 25% weak to enamel then both the 4th and 5th generation adhesives in pooled data studies. Several respected clinicians have utilized 6th generation adhesives for bonding to dentin after selectively etching the enamel.

Seventh generation

The seventh-generation bonding systems was introduced in late 1999 and early 2005. The seventh generation or one-bottle self-etching system represents the latest simplification of adhesive systems. With these systems, all the ingredients required for bonding are placed in and delivered from a single bottle [26, 31]. This greatly simplifies the bonding protocol as the claim was that could be achieved consistent bond

strengths while completely eliminating the errors that could normally be introduced by the dentist or dental assistant who had to mix the separate components with other more complicated systems. However, incorporating and placing all of the chemistry required for a viable adhesive system into a single bottle, and having it remain stable over a reasonable period of time, poses a significant challenge [26]. These inherently acidic systems tend to have a significant amount of water in their formulations and may be prone to hydrolysis and chemical breakdown [31, 32]. Furthermore, once placed and polymerized, they are generally more hydrophilic than two-step self-etching systems; this condition makes them more prone to water sorption, limits the depth of resin infiltration into the tooth and creates some voids [33]. The advantage of this generation was not any mixing required and the bond strengths were consistent. However, the seventh-generation adhesives have proven to have the lowest initial and long-term bond strengths of any adhesive on the market today that may be considers as disadvantage. Seventh generation adhesives involve the application of etch, primer, and adhesive which have already been mixed, followed by light curing the tooth.

Seventh generation adhesives are "all-in-one" [34] if there has ever been such a thing. The clinical and scientific data on these adhesives proves that they are hydrophilic and degrade more rapidly. In addition, the chemistry must be acidic, as etch is involved in this liquid, and this has been shown to adversely react with the composite initiator systems.

Eighth generation

In 2010, voco America introduced voco Futura bond DC as 8th generation bonding agent, which contains nanosized fillers [35]. In the new agents, the addition of nano-fillers with an average particle size of 12 nm increases the penetration of resin monomers and the hybrid layer thickness, which in turn improves the mechanical properties of the bonding systems [36, 37]. Nano-bonding agents are solutions of nano-fillers

Table 1: Advantages and disadvantages of self-etching and total-etching systems

	Self-etching system	Total-etching system
Advantages	+ Simple procedures + Reduced post-operative sensitivity [38,39] + High bond durability to dentin [40] + Less technique sensitivity (wet bonding is not required) + Esthetic (thin bonding layer)	+ High bond strength to uncut enamel [41] + Excellent marginal integrity [42,43,44,45,46]
Disadvantages	Low bond strength to uncut enamel [41] - Poor marginal integrity[42,43,44,45,46] (marginal defect and discoloration)	Complicated procedures - Higher risk of post-operative Sensitivity[38,39] - Low bond durability to dentin [40]

Table 2: Classification of dental bonding systems by generations.[47]

Generation	Number of steps	Surface pre-treatment	Components	Shear bond strength (MPa)
1st	2	Enamel etch	2	2
2nd	2	Enamel etch	2	5
3nd	3	Dentine conditioning	2-3	12-15
4th	3	Etch and rinse	3	25
5th	2	Etch and rinse	2	25
6th	1	Self-etch adhesive	2	20
7th	1	Self-etch adhesive	1	25
8th	1	Self-etch adhesive	1	Over 30

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