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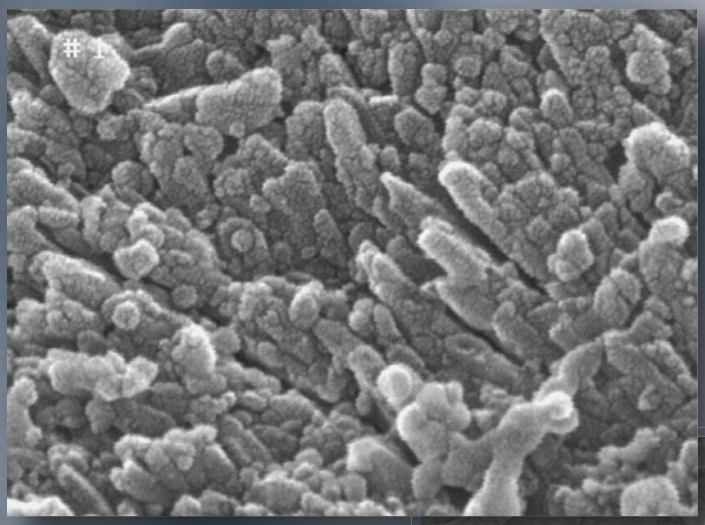

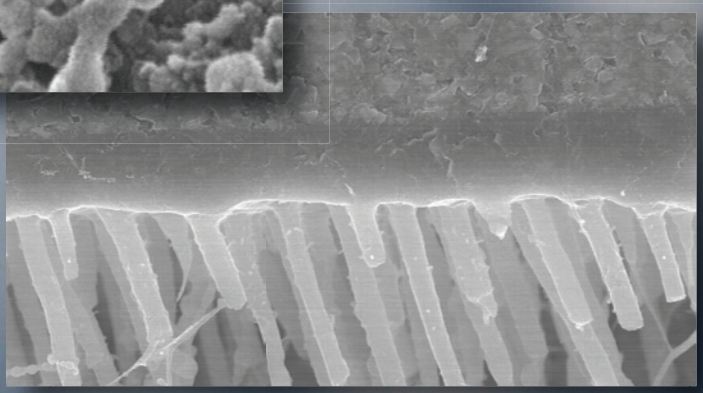

The Progression of Dental Adhesives

A Peer-Reviewed Publication
Written by Ara Nazarian, DDS

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Educational Objectives

Upon completion of this course, the clinician will be able to do the following:

1. Be knowledgeable about the evolution of bonding adhesives
2. Know the attributes of an ideal bonding agent
3. Be knowledgeable about the properties of the seventh-generation adhesives and the advantages they offer
4. Know the applications that seventh-generation adhesives can be used for and understand the techniques that should be used

Abstract

There has been dramatic progression in the adhesion of dental adhesives and resins to enamel and dentin in the 40 years since Buonocore[1] introduced the technique of etching enamel with phosphoric acid to improve adhesion to enamel. The first dental adhesives bonded resins to enamel only, with little or no dentin adhesion. Subsequent generations have dramatically improved bond strength to dentin and the sealing of dentin margins while retaining a strong bond to enamel. With more patients demanding metal-free dentistry, the use of dental resins as cements as well as direct and indirect restorations will continue to increase. This article discusses the progression of dental adhesives up to the most recent generation, in which all components are contained in a single bottle or unit-dose container and applied using a one-step technique that requires no mixing.

Overview

Over the past 45 years, dental bonding systems have evolved with variations in chemistry, application, mechanism, technique, and effectiveness. This evolution accompanied the development of improved esthetic dental materials, notably composite resin and ceramic, and an increasing demand by patients for esthetic dentistry. In 1999, approximately 86 million direct resin restorations were placed. With respect to indirect restorations, approximately 2.5 million veneers, 38 million resin/ceramic crowns, and 1.1 million ceramic/porcelain inlays were placed, in addition to metal-based crowns and bridges and core/post and core build-ups.[2] All direct resin restorations require bonding, and indirect restorations either require or are candidates for bonding. As the demand for bonded esthetic restorations has continued to increase, the evolution of bonding agents has accelerated. Let us quickly review dental adhesives according to a series of generations, allowing us to understand the characteristics of each group.

All direct resin restorations require bonding

History of Bonding Agents

First and Second Generation

The first- and second-generation bonding agents used during the 1960s and 1970s did not recommend etching the dentin, but instead relied on adhesion to the attached smear layer.[3] The weak bond strength (2MPa–6MPa) to the smear layer still allowed dentin leakage with clinical margin stain.[4]

Third Generation

The third-generation systems of the 1980s introduced acid etching of dentin and a separate primer designed to penetrate the dentin tubules as a method to increase bond strength.[3] These systems increased bond strength to dentin (12MPa–15MPa) and decreased dentin margin failure. With time, however, margin staining caused clinical failure.[4]

Fourth Generation

The fourth-generation adhesive systems of the early 1990s used chemistry that penetrated both etched and decalcified dentin tubules and dentin substrate, forming a "hybrid" layer of collagen and resin. Fusayama[5] and Nakabayashi[6] described the penetration of resin into dentin as giving high bond strengths and a dentin seal. In fact, Kanca[7] introduced the idea of "wet bonding" with these systems. Products in this category include All-Bond® 2 (Bisco), OptiBond® FL (Kerr), and Adper™ Scotchbond™ Multipurpose (3M ESPE). These bonding agent systems have the longest track record as far as research goes and they perform well clinically. In fact, OptiBond FL, an 18-year-old product, received the Product of the Year award from *Reality* magazine.[8] Bond strengths for these adhesives were in the low- to mid-20MPa range and significantly reduced margin leakage compared to earlier systems.[4] 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. Because of the complexity of multiple bottles and steps, dentists began requesting a simplified adhesive system.

Fourth generation adhesive systems were very technique sensitive

Fifth Generation

That request ushered in the fifth-generation bonding systems, introduced during the mid 1990s, which combined primer and adhesive in one bottle while maintaining high bond strengths. Products in this category include Excite (Ivoclar Vivadent), OptiBond® Solo Plus™ (Kerr), Prime and Bond® NT (Dentsply), and Adper™ Singlebond™ (3M ESPE). Unit-dose packaging introduced during this era

Table 1. Evolution of Bonding Adhesives

1960s and 1970s First and Second Generation
Did not recommend dentin etching.
Relied on adhesion to smear layer.
Weak bond strength.

1980s Third Generation
Acid etching of dentin.
Separate primer.
Increased bond strength.
Margin staining caused clinical failure over time.

Early 1990s Fourth Generation
Acid etching of dentin.
Separate primer.
Increased bond strength.
Margin staining caused clinical failure over time.

Early 1990s Fourth Generation
"Hybrid" layer of dentin and collagen.
Dentin seal.
Concept of "wet bonding" introduced.
Technique sensitive.

Mid 1990s Fifth Generation
Combined primer and adhesive in one bottle.
Maintained high bond strengths.
Unit-dose packaging introduced.

Late 1990s, Early 2000s Sixth Generation
"Self-etching" primers.
Reduced incidience of post-treatment sensitivity.
Bond strengths lower than fourth- and fifth-generations.

Late 2002 Seventh Generation
"All-in-One".
Combines etching, priming and bonding.
Single solution.
Good bond strength and margin sealing.

provided fresh chemistry for each procedure. Yet controlled etching, surface wetness, and resin placement continued to be a clinical challenge for some clinicians.

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 separate acid-etching step was eliminated by incorporating an acidic primer that was placed on the enamel and the dentin after tooth preparation.[3] Several variations involved either mixing the acidic primer and adhesive before placement on the dentin and enamel, or leaving the primer on the tooth and then placing the adhesive over the primer. Some products in this class are Clearfil® SF Bond (Kurarray), Simplicity™ (Apex), Adper™ Prompt™, and L-Pop™ (3M ESPE). These systems were also reported to reduce the incidence of post-treatment sensitivity found in previous systems.[8] However, the bond strength to dentin and enamel is lower than fourth- and fifth-generation systems[4] (Table 1).

Ideal Bonding Agent Attributes

Attributes of an ideal bonding agent would include high bond strength, a thin film thickness to ensure easy and complete seating of restorations, shelf stability, and post-placement stability. The ability to release fluoride is desirable to help prevent the onset of secondary caries, which is the leading reason for replacement of existing restorations.[9] In addition, the bonding agent should be user-friendly—ideally a one-step procedure requiring no mixing, with the versatility to be used for multiple types of restorations (indirect and direct, resin/ceramic, and metal), and tolerant of both moist and dry environments (Table 2).

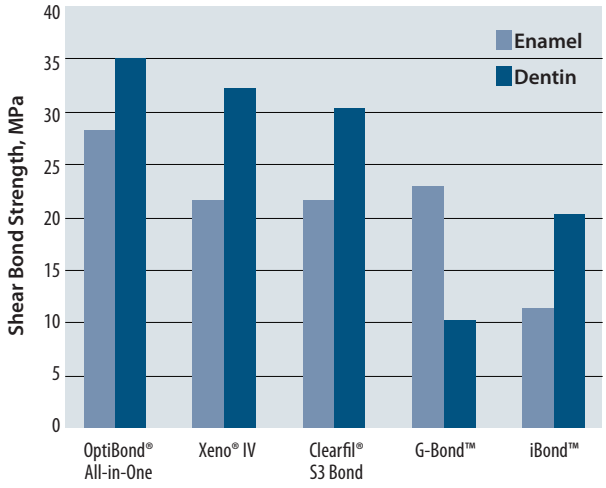
Table 2. Ideal Bonding Agent Attributes

High bond strength
Thin film thickness
Fluoride-releasing
User-friendly
Suitable for moist and dry environments
Stability

Seventh Generation Bonding Systems

The latest category, seventh-generation bonding systems, is the "all in one" adhesives that combine etch, prime, and bond in a single solution.[8] This adhesive category was introduced in late 2002. Laboratory studies show bond strengths and margin sealing to be equal to sixth-generation systems.[4] Products in this category include iBond™ (Heraeus), Xeno® IV (Dentsply), G-Bond™ (GC), Complete (Cosmedent), and OptiBond® All-In-One (Kerr).[8] Both OptiBond All-

Figure 1. Shear Bond Strength – All-In-One Adhesive Systems



in-One and Xeno IV are fluoride releasing, while iBond and G-Bond are not.

The all-in-one adhesives are user-friendly, and most offer both a bottle and a unit-dose version. There are variations on other attributes depending on the product used. Shear bond strength, a key attribute in dental adhesives, varies considerably depending on the self-etch adhesive used. (Figure 1)

> The all-in-one seventh generation adhesives are user-friendly and most offer both a bottle and a unit-dose version

All-In-One Bond Dental Adhesive System

OptiBond All-In-One is a single-component, self-etch adhesive that eliminates multiple steps when bonding direct and indirect restorations. Clinicians have everything they need for etching, priming and bonding in one material. OptiBond All-In-One is a light-cured adhesive that provides adhesion to all surfaces and substrates. Its ternary solvent system provides enhanced shelf-life stability and effective enamel etching for long-term bond performance.

According to some independent studies provided by Kerr Corporation, OptiBond All-In-One delivers excellent penetration into dentin tubules, offering exceptional bond strength and protection against microleakage and postoperative sensitivity.

Its unique etching capability enables the most effective enamel etching of any single-component adhesive, creating a deeper-etched surface for higher mechanical retention and chemical bonding. Scanning electron microscopy (SEM) of etched enamel shows the deep etching obtained using this capability (Figure 2), and SEM of the adhesive-dentin-bonding interface shows the deep tags that result from use of this system in dentin (Figure 3).

Figure 2. Etched Enamel

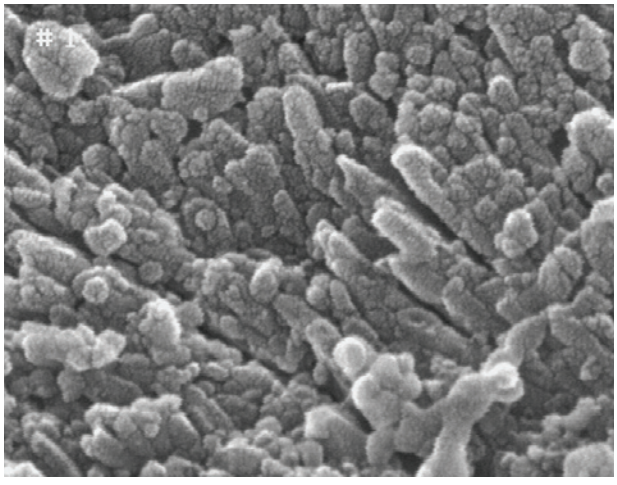


Figure 3. OptiBond All-in-One Adhesive-Dentin-Bonding Interface

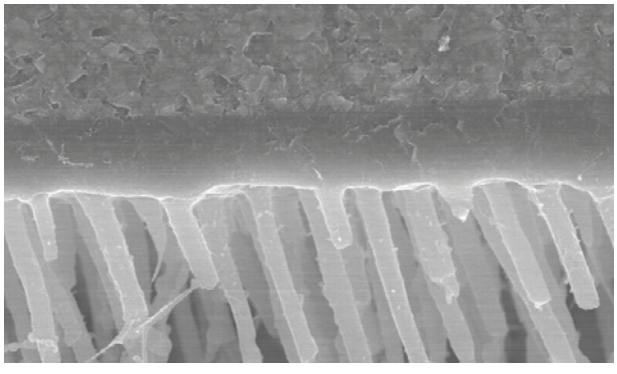


Figure 4. Preoperative View of Smile

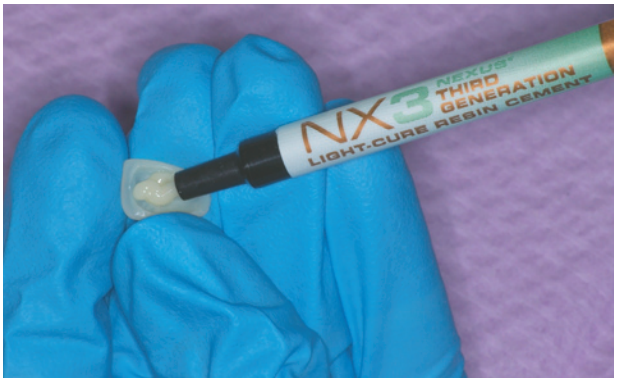
Figure 5. Preoperative Retracted View

Figure 6. Preoperative Palatal View

Figure 7. Preparations

Figure 8. Restorations

Figure 9. Loading of Veneers



I have found that the low film thickness makes it easier to seat indirect restorations, creating a better fit. OptiBond All-In-One is available in both a 5 ml bottle delivery and a convenient free-standing Unidose™ device.

OptiBond All-in-One offers exceptional bond strength and protection against microleakage and post-operative sensitivity

Case Presentations

Seventh Generation Bonding Agents are ideal for bonding indirect restorations, and for direct composite resin (where bonding is mandatory regardless of the material and technique being used).

Case Presentation 1 — Indirect Restorations

A patient sitting for an initial consultation was dissatisfied with her smile (Figure 4). Clinical examination revealed a Maryland bridge from teeth #6–#8 with failing margins (Figures 5, 6). The patient stated that the bridge had been recemented a couple of times since its original placement five years prior. Tooth #10 had an existing veneer restoration to correct a peg lateral. Also, tooth #11 and tooth #12 were inverted. Probing depths were within normal levels in the anterior region, and the patient's periodontal health was within acceptable limits.

The *Smile Guide Book* (Discus Dental) was used to complete the smile analysis necessary for predesigning the case. Her existing bridge was asymmetric, and the patient preferred a more complete and uniform smile. In order to achieve this, the shape selected would be rounder and the embrasures between the teeth would be smaller. The lip line edge versus the incisal edge of the teeth suggested that the patient could tolerate lengthening of the incisal edges. The results of the smile analysis, diagnostic study models, and preoperative clinical photography were reviewed with the patient to determine the desired treatment plan for improving her smile and function. Since the patient's complaint was extreme dissatisfaction with the whole appearance of her smile, it was decided to incorporate a metal-free bridge material (Lava™, 3M) for the missing lateral and porcelain veneers on the adjacent teeth. The proposed treatment plan of a zirconium bridge (Lava, 3M) from #6–#8 and porcelain veneers from #9–#11 was reviewed with the patient, and she was excited to start the treatment.

After anesthetic was administered, a diamond bur was used to prepare the anterior teeth. It was very important to adhere to the preparation guidelines for the zirconium bridge in order to ensure functional and esthetic predictability. The laboratory required a minimum of 0.8 mm reduction of the facial walls and a minimum of 1.5 mm of incisal reduction.

Figure 10. Postoperative Retracted View

Figure 11. Postoperative Occlusal View

Figure 12. Postoperative View of Smile

Internal line angles were to be rounded, and a butt joint margin was required (Figure 7). Also, an ovate area was created in the gingiva at the pontic site of tooth #7 with an Odyssey® Laser (Ivoclar Vivadent) to create a more harmonious emergence profile for the pontic. Impressions were taken using a quick-setting polyvinylsiloxane (PVS) impression material (Take 1®, Kerr). These impressions, a bite registration, and photos were then forwarded to the lab for fabrication of the final restorations.

Provisionalization

A provisional restoration, which was significant to the overall treatment, was made from an impression of a composite mock-up. Using Fill-In™ (Kerr) temporary material, this mold was quickly filled and placed on the patient's prepared dentition. Within a couple of minutes, the temporary had cured and was ready for shaping. Gross shaping and contouring were achieved using flexible discs (OptiDisc™, Kerr). A flame-shaped fine diamond was used to shape and trim the margins and embrasure spaces. The next day, the patient returned for evaluation of size, shape, color, and bite. Already, she exhibited excitement and confidence with her provisional restorations.

Laboratory

During the laboratory phase, the full arch polyvinylsiloxane impressions were used to pour up a master model on which the restorations would be based. The master model was segmented into individual dies that were trimmed and pinned to determine the manner by which the final restorations would integrate with the existing soft tissue. A silicone incisal matrix of the provisional restorations was created to guide the placement of incisal effects and edge position in the subsequent ceramic buildup. In addition, comprehensive color mapping ensured that the definitive esthetic results would meet patient expectations.

Cementation

The patient was anesthetized and a nonlatex split-rubber dam was placed. Prior to try-in of the definitive restorations to verify fit and shade, the provisional restorations were removed and any remaining cement was cleaned off the prepared dentition using Preppies Paste. The restorations were tried in to verify marginal fit, contour, contacts, and shade (Figure 8). Following patient approval of the final restorations, the cementation process was initiated.

The veneer restorations were treated with 37 percent phosphoric acid for 20 seconds, rinsed, silanated, and air dried for one minute. OptiBond All-in-One was applied to the preparations with a scrubbing motion for 20 seconds. A second application was placed on the preparations with a scrubbing motion for 20 seconds and then gently air dried for five seconds with a medium force of air. The adhesive was light cured for 10 seconds per tooth. Since the film thickness of OptiBond All-In-One adhesive is approximately 5 microns after curing, there was no concern during the seating process.

NX3 Nexus® Third Generation (Kerr) light-cure resin cement was applied to the veneer restorations (Figure 9).

The restorations were then placed on the preparations and, while they were firmly held in place, a rubber tip applicator removed all excess luting cement from the margins. A thin layer of glycerin was then applied to the margins to prevent the formation of an oxygen-inhibiting layer. The restorations were tacked at the gingival margin. Once the veneer restorations were placed, the

Figure 13. Preoperative View of Amalgam Restorations

Figure 14. Amalgam Restorations Removed

Figure 15. Preparations with OptiBond All-in-One

Figure 16. Finished Composite Restorations

bridge restoration was seated using Maxcem (Kerr) resin cement.

While the restorations were still firmly held in place, the restored dentition was flossed and any excess luting cement was carefully removed. Once the majority of the excess cement was removed, the restored dentition was completely light-cured from both the facial and lingual sides. Any residual cement was removed with a #15 scalpel and finished with a fine diamond and polishing points. The occlusion was verified and adjusted. Overall health and structure of the soft tissue and restorations were very good. As seen in the postoperative photos immediately after seating, the restorations exhibited a nice esthetic look and the patient was extremely happy (Figures 10–12). Also, upon review two weeks later, the patient had no complaints of sensitivity.

Case Presentation 2 — Direct Composite Restorations

A patient sitting for an initial consultation was concerned about some sensitivity on the left-hand side in her upper back teeth. Clinical examination revealed that the occlusal amalgam restorations on tooth #14 and tooth #15 were defective, with leaking margins. The two teeth also had fractures adjacent to the amalgams, caries was evident, and a mesial defect was present on tooth #15 (Figure 13). All other teeth were clinically sound, there was no recession present, the patient's periodontal health was within acceptable limits, and she had no other complaints.

After discussion on the available options utilizing the DemoDent anatomical model (DemoDent PLLC), the patient elected to have the restorations replaced with bonded composite restorations. After anesthetic was administered, diamond burs were used to remove the defective amalgams and adjacent caries (Figure 14).

Upon removal of the amalgams, it was found that caries was present in the deepest regions of the preparations. This was carefully removed using a slow-speed handpiece with large round burs. The preparations were extended to remove the caries in the palatal fissure regions, and to prepare the mesial box in tooth #15. A sectional matrix band (Garrison) was placed over the mesial margin of tooth #15 in such a way that its position and shape would enable placement of a composite with an optimal mesial contour. Once tooth #15 was isolated by the matrix band, both molars were dried and an all-in-one adhesive (OptiBond All-in-One) was applied to the preparations and adjacent enamel for 20 seconds, and then gently air dried for five seconds (Figure 15).

The restorations were completed using light-cured flowable composite (Premise flow and Premise, Kerr), after which the matrix band was removed, the occlusion was verified and adjusted, and the restorations were finished and polished (Figure 16).

Summary

Dental adhesives have dramatically changed the options available for restoration placement since their introduction more than forty years ago. Initially, these required a longer etching time and were only recommended for etching and bonding of the enamel. Dental adhesive developments shortened the etching time and enabled etching and bonding of dentin as well as enamel. However, early generation adhesives had weaker bond strength and allowed marginal leakage at the restoration margin. Today, clinicians have a variety of esthetic and functional materials to choose from when faced with the need to perform cosmetic dentistry. As dentists, we are always looking for products that are quick and simple to use yet high-performing and effective. OptiBond All-In-One single component self-etching dental adhesive and other similar seventh-generation adhesives offer great benefits, whether used as the main adhesive or as an adjunctive bonding agent. The versatility of seventh-generation dental adhesives enables their use for both indirect and direct restorations, providing for excellent marginal seal and high bond strength.

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Author Profile

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