Continuing Education

Understanding Dentinal Adhesives

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Educational objectives
Upon completion of this course, participants should be able to achieve the following:

• Understand the mechanism of hybridization and the principles associated with adhering resin to the surface of dentin.
• Understand the basic differences amongst the various generations of dentin bonding agents presently on the market.
• Acquire a working knowledge of the odontoblast and its relationship to clinical behavior.
• Understand the etiology of postoperative sensitivity and methods recommended for prevention.

Abstract
The introductory combination of composite resin and dentinal bonding agents represents one of the most exciting phases of aesthetic restorative dentistry. Although the quest for a system that would permit adhesion to dentin began nearly 35 years ago, it has been only during the last 15 years that major progress has been achieved.

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The adhesion of resin to tooth structure has been so successful that it has dramatically changed the way that dentistry is practiced. Specific examples include design and dimension of the preparation, lesser dependence on mechanical retention, aesthetics and the potential for increasing the fracture resistance of the restored tooth.

The adhesion of resin to the surface of dentin is through a process of hybridization or superficial diffusion. Hybridization into decalcified dentin basically is a rather straightforward process. In essence, it consists of first removing the hydroxyapatite or calcium/phosphate component of the dentin. Depletion of the mineral phase on the surface amounts to no more than 10 microns. Demineralization of the peritubular dentin is also approximately 10 microns. The actual depth of penetration into the dentinal tubule however, may be as great as 100 microns. Once accomplished the low viscosity bonding agent penetrates and fills all of the vacancies created by the acid etching or the demineralization process. While the depth of penetration is limited to the decalcified zones, the tubular penetration is influenced by the presence of odontoblastic fluids and hydraulic pressures.

Hybridization then is a process of replacing demineralized dentin with a low viscosity polymer. While the process is straightforward and simple, the degree of success is highly dependent upon the clinician's ability to follow the manufacturer's directions in a scrupulous manner. Once accomplished however, a number of important objectives can be achieved. These include adhesive bonding of the composite resin to the entire surface of the cavity preparation. The need for mechanical undercutting can be dramatically reduced. This also leads to the potential for reducing the size of the cavity preparation, thereby preserving natural tooth structure. The second goal achieved is provision of excellent protection against microbial invasion. The final objective is a means for eliminating the potential for postoperative sensitivity. All this can be attributed to the studies conducted by Professor Nobuo Nakabayashi of Japan.

Although not given top billing, the odontoblastic process plays a very important role in the practice of dentistry. Much if not most of the postoperative sensitivity associated with dental restorative procedures, can be attributed to opened dentinal tubules and the odontoblastic process itself. These cells are commonly located between the surface of the pulpal chamber and the predentin region of the dentin. Generally they are lined up in single rows each possessing an extension or proboscis (odontoblastic process) that extends into the opened dentinal tubules. While these processes commonly extend to about a third of the thickness of the dentin, they can be found beyond the dentin and sometimes into the overlying enamel itself. These processes, which are illustrated in Fig. 1, are surrounded by a clear plasma-like fluid. Extremely sensitive to negative pressures they produce a painful response which is commonly referred to as post-operative sensitivity (POS).

The odontoblast plays a number of important roles. These include the following: 1) maintenance and repair of the dentin, 2) responder to dentinal trauma following caries and restorative procedures and 3) generation of a painful response when subject to anything that produces a negative pressure on its surface. Regarding pain, any condition that places the process in a state of compression will generate such a response. Common clinical stimuli that produces a negative pressure and thereby POS include...
It is important to note that the intrinsic capacity to repair dentin through the odontoblast is dependent upon the vitality of this cell. The problem of POS can be prevented or eliminated by sealing the dentinal tubules and the intertubular dentin. This is accomplished by the diffusion of the dentin bonding agent into the surface structure of the dentin and is known as “hybridizing.” Sealing or hybridizing of the dentin accomplishes three specific objectives: 1) excellent protection against microbial invasion into the pulpal chamber, 2) elimination of the potential for POS and 3) constitutes a mechanism for adhesive bonding.

Generations of dentin bonding agents

Presently, there are four generations or types of dentin bonding agents available to the clinician. Identified as fourth through seventh, each is characterized by the procedure used to generate the hybrid zone. The basic difference amongst the four generations of dentinal adhesives can be described by the following number of components or procedure (Table 1), top left.

The fourth generation (Total Etch) requires three separate steps. These include 1) Etching, 2) Primer and 3) Adhesive. The fifth generation (Total Etch) requires etching followed by application of the primer/adhesive (one bottle). The sixth generation (Self-Etch) contains the etching agent and the primer in the first bottle and the adhesive in a second bottle. The seventh generation system (Self-Etch) contains all three components in one bottle.

Examples of the various generations (alphabetical order) are given in Table II (bottom left).

Pre-etching

One of the problems associated with the self-etching dentinal adhesives is the potential for insufficient etching of the enamel. As a result, the bond strength of the overlying composite resin to the enamel portion of the preparation may be inadequate. As a result, many clinicians have reported the presence of brown lines along the margins of the restorations. Such findings suggest the presence of microleakage in these regions.

The problem of inadequate bonding to the enamel can be addressed in two different ways. The first consists of pre-etching the enamel before the application of the bonding agent. This is commonly accomplished by using a 37% phosphoric acid gel for about 15 seconds. Such a procedure will assure proper bonding of the dentin bonding agent and thereby eliminate the presence of the brown lines along the enamel margins. These brown lines, by the way, are created by an influx of dissolved food particles or dark liquids such as tea or coffee into the restoration/preparation interface.

The second method consists of applying the sixth or seventh generation bonding
agent first on the enamel portion of the cavity preparation followed by application to the dentin surfaces. Procedurally, this is achieved by a continuous application of the agent beginning on the margins of the preparations working in a spiral direction towards the dentin itself. Such a process should take approximately 15 seconds. At this point the bonding agent should be applied to surface the dentin. The procedure will automatically cause the bonding agent to contact the enamel twice as long as it will to the dentinal surfaces. Such a method commonly produces adequate etching of the enamel and generation of clinically acceptable bond strengths.

The second method generally is recommended over the first. Pre-etching of the enamel may cause a greater depth of dissolution of the hydroxyapatite than the self-etching bonding agent is capable of filling in. This then may result in inadequate bonding and development of the hybrid zone. Consequently, postoperative sensitivity may once again become a major problem.

**Proof of adequate diffusion of the dentin bonding agent**

The success of bonding will depend in part upon total diffusion of the bonding agent into the decalcified dentinal structure. Many clinicians have difficulty in determining whether or not this action has taken place. A simple test is offered here to ascertain the level of diffusion. Upon application of the bonding agent over a 15-second period the surface is carefully air dispersed. At this point the process is carried out the second time. After air dispersing, the surface will appear highly reflective of light. Leave the surface alone for an additional 15 seconds. If it remains highly reflective of light at this time, it is highly probable that the decalcified dentin is thoroughly saturated with the bonding agent. It is then safe to light-cure the preparation. If an insufficient amount of bonding agent has been applied, the highly glossy surface will begin to lose its reflectiveness thereby becoming dull in appearance. In fact it is possible that the surface will appear as if no dentin bonding agent was ever applied. Such a technique can be used for determining the level of diffusion for all generations of dentinal adhesives currently on the market. This technique is recommended as a clinical check whenever a new dentin bonding agent is employed or when various conditions changes such as aging of the bonding agent or perhaps when bonding to highly sclerotic or aged dentinal surfaces. Incidentally, lack of adequate diffusion of the adhesive into the dentinal surfaces is probably one of the greatest causes of adhesive failure and postoperative sensitivity.

**Protection against postoperative sensitivity**

Undoubtedly, one of the biggest problems associated with the posterior composite resin has been postoperative sensitivity. Sensitivity is commonly generated by drinking cold liquids and/or by masticating on the surface of the restoration itself. Since the occurrence of postoperative sensitivity has been so significant, the sixth generation dentinal bonding agent was offered to the profession. The rate of success has been so overwhelmingly great that that majority of practitioners have converted to this system. The reason for eliminating the potential for postoperative sensitivity is quite interesting. In essence, the total etch bonding systems (fourth and fifth) consist of the demineralization phase and the resin diffusion phase. When the first stage is completed, the second stage is carried out. Since the success of these older generation agents is dependent upon the ability of the monomer to diffuse into the decalcified regions, postoperative sensitivity is a distinct possibility. A graphic illustration of the two stages (demineralization and diffusion) is depicted in Fig. 3. As can be seen, the first stage must be completed before the second stage can begin. A graphic illustration of the self-etching process is shown in Fig. 4. Note that in this case the decalcification process and resin uploading occur simultaneously. In other words, as soon as the demineralization
process begins, so also begins the process of resin diffusion. This then results in the elimination of any potential of zones or regions of unprotected collagenous structure. It should be pointed out that any problems of sensitivity associated with the pre self-etching systems could be avoided by careful adherence to directions offered by the respective manufacturer.

Conclusions

The dentin bonding agents have been clinically successful for the last decade and a half. Although the ultimate bond strengths have remained nearly the same during this period, the systems have been designed to be appreciably more user friendly. Nonetheless, the improvements in handling were accompanied by a number of major problems including postoperative sensitivity, incompatibility with dual cure resin systems and less than desirable etching and bonding to enamel surfaces. One of the biggest issues has been the potential for incompatibility of the post fourth generation dentin bonding agents with dual cured core materials and luting agents. Fortunately however, some of the seventh generation systems are addressing this problem. The newest generation of adhesives (seventh) appears to be an exciting advancement in terms of technique sensitivity, simplicity and without as many problems as related to post operative sensitivity.

References


Author’s Bio

Dr. Karl F. Leinfelder, a native of Wisconsin, earned both his Doctor of Dental Surgery and Master of Science (Dental Materials) degrees from Marquette University. After serving for eight years on the faculty at Marquette, he joined the faculty at the University of North Carolina School of Dentistry where he attained the rank of Professor and Director of Biomaterials Clinical Research in the Dental Research Center.

In 1983, he joined the School of Dentistry at the University of Alabama and is the recipient of the Joseph Volker Chair. He also served as Chairman of the Department of Biomaterials until 1994. Presently he holds positions at both universities, adjunct professor at University of North Carolina and Professor Emeritus at the University of Alabama.

Recipient of the Dr. George Hollenbeck award (1995) as well as the Norton N. Ross award for outstanding clinical research (1997), and the American College of Prosthodontists Distinguished Lecturer Award (1998). He has served as associate editor of the Journal of the American Dental Association and is a dental materials research consultant for numerous materials companies. Dr. Leinfelder has published about 250 papers on restorative materials, authored more than 150 scientific presentations, a textbook on restorative materials and techniques and has lectured nationally and internationally on clinical biomaterials.

Disclosure: Dr. Leinfelder declares being a consultant for Heraeus Kulzer and Pentron. He is also a stock shareholder (directly purchased) of 3M and has received an honorarium from Sybron Kerr.
1. The average depth of penetration of phosphoric acid on the surface of dentin is how many microns?
   a. one
   b. five
   c. ten
   d. fifty
   e. two hundred

2. The odontoblast cells are commonly located in which of the following regions?
   a. within the pulp tissue
   b. on the surface of the pulp
   c. at the dentinal-enamel junction
   d. within the dentin

3. Hybridization accomplishes which of the following?
   a. protects against bacterial invasion into the pulp
   b. eliminates postoperative sensitivity
   c. provides a means for adhesion to tooth structure
   d. provides the potential for reducing the preparation size
   e. all of the above

4. Who was the person responsible for the development of the hybridization concept?
   a. Ralph Phillips
   b. Michael Buonocore
   c. Nobuo Nakabayashi
   d. John Gwinnett
   e. Raphael Bowen

5. The odontoblasts play a number of important roles which include the following:
   a. maintenance and repair of the dentin
   b. responder to dental trauma following caries
   c. responder to the restorative process
   d. generation of a painful response when subjected to negative pressures
   e. All of the above

6. Common chemical stimuli that place the odontoblastic process in a state of compression include which of the following?
   a. ionic solutions of salts and sugars
   b. elevated temperatures
   c. composite resin restorations
   d. body temperature water
   e. none of the above

7. Currently there are several generations of dentinal bonding agents available to the clinician. Which of the following contains the etching agent, the primer and the adhesive all in one?
   a. fourth
   b. fifth
   c. sixth
   d. seventh

8. Which generation of dentinal adhesive first provided an appreciable protection against postoperative sensitivity?
   a. third
   b. fourth
   c. fifth
   d. sixth
   e. seventh

9. When using a sixth or seventh generation dentinal bonding agent, what is the most accepted means for achieving proper etching of the enamel structure?
   a. use citric acid
   b. pre-etch with maleic acid
   c. pre-etch with phosphoric acid
   d. apply the bonding agent to the enamel for a period of time twice as long as the dentinal surface
   e. apply the bonding agent to the enamel and the dentin for an equal amount of time

10. One of the greatest sources of bonding failures is which of the following?
    a. using the "total-etch" technique
    b. over etching
    c. inadequate diffusion of the bonding agent into the dentin
    d. washing for more than 15 seconds
    e. using the "self-etch" technique