New perspectives on dentin adhesion--differing methods of bonding

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Abstract
The advent of adhesive dentistry has had a dramatic effect on the practice of aesthetic dentistry, significantly expanding the range of treatment alternatives that clinicians can provide for their patients. Although adhesion is generally associated with the total bonding technique, adhesive systems can be applied in several different manners that include selective, separate, and secure bonding. It is the goal of this article to present the different bonding procedures, to explain the rationales behind each, and to formulate their indications.

Reference

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NEW PERSPECTIVES ON DENTIN ADHESION — DIFFERING METHODS OF BONDING

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The advent of adhesive dentistry has had a dramatic effect on the practice of aesthetic dentistry, significantly expanding the range of treatment alternatives that clinicians can provide for their patients. Although adhesion is generally associated with the total bonding technique, adhesive systems can be applied in several different manners that include selective, separate, and secure bonding. It is the goal of this article to present the different bonding procedures, to explain the rationales behind each, and to formulate their indications.

Key Words: adhesion, bonding, composite, polymerization, shrinkage

In recent years, adhesion has become fundamental to restorative dentistry. Minimally invasive restorations, amalgam alternatives, veneers, metal-free crowns, slot fixed partial dentures, and even posts rely on adhesion. Nevertheless, adhesion to the tooth surface is always in opposition to the polymerization shrinkage of the composite material. The negative effects of polymerization shrinkage (e.g., marginal gaps or marginal enamel fractures) become particularly pronounced in restorative systems with a large volume of the shrinking composite and a small free surface area. In such a situation, volume loss caused by polymerization shrinkage of the composite can hardly be compensated for by the flow of the material from the free surface during the gel phase of polymerization.

Free surfaces may be found in instances where the restorative material does not adhere to the tooth (i.e., on the outer surface of the restoration), and inside the cavity if no adhesion between the restoration and tooth is present in this area (Figures 1 and 2). The ratio between the free and bonded restoration surface is called the configuration factor or the "C-factor." A high C-factor makes it difficult to establish optimal adhesion. Even if this objective can be established initially, a high C-factor leads in these instances to a preload restorative system that may be prone to gap formation during loading. It has been demonstrated that total bonding, creating the highest possible C-factor in a given cavity configuration, is not always the

Figure 1. Illustration of total bonding. The multiwall cavity with totally bonded restoration results in a high configuration factor.
most appropriate bonding procedure. This article seeks to define the different methods of bonding, to explain their rationale, and to provide information on their indications.

**Bonding Procedures**

By using the total bonding technique, adhesion is established to the entire surface of the cavity. As a consequence, no free surface areas are present within the cavity. This type of adhesion is achieved through the use of an enamel/dentin bonding agent and the omission of a base. If the adhesion is stronger than the polymerization shrinkage stress and/or the stresses under function, the interface between restoration and tooth remains perfectly sealed (Figure 3). In certain cavity configurations, however, shrinkage stresses may become higher than the bond strengths — even of the most potent adhesive systems. This results in partial delamination of the adhesive system from the tooth surface. If the delamination occurs in the marginal region, marginal gaps and/or enamel fractures are the consequences (Figures 4 through 7). Clinically, they appear as "white margins," marginal discolorations, fissures, or even recurrent caries (Figure 8). If the delamination occurs within the cavity or dentin that is in communication with the pulp, dentin tubules become unprotected, which results in postoperative sensitivity (Figure 9). As a rule, total bonding is well tolerated by restorative systems with a small volume of shrinking composite, with a low C-factor, and when combined with potent adhesive systems.

![Figure 2. Illustration of selective bonding: By applying this technique, a lower configuration factor can be created in the cavity design from figure 1 since adhesion is established to the margins only.](image2)

![Figure 3. Confocal laser scanning micrograph (CLSM) of total bonding at the occlusal floor of a Class I cavity; the dentin is perfectly sealed (fieldwidth = 202.5 μm).](image3)

![Figure 4. CLSM of total bonding at the occlusal margin of a Class I cavity. Enamel crack (arrows) caused by polymerization shrinkage in a totally bonded restoration (red zone = bond).](image4)

![Figure 5. SEM of total bonding at gingival margin of prepared Class II cavity. Enamel cracks (yellow arrows) caused by polymerization shrinkage prior to in vitro stressing (x200).](image5)

Selective bonding confines the adhesion of the restoration exclusively to the margins of the preparation. This is irrespective of whether the margins are located in enamel or dentin. This does not mean that adhesion is limited to a width of mere microns at the margin of the restoration. The thickness of occlusal enamel is approximately 1.2 mm, and this is the area where adhesion is
seal dentin, it must not adhere to the restorative material. For this purpose, a chemically cured glass-ionomer cement (GIC) base may be used. It can seal dentin and, if used as a build-up base, may reduce the volume of the cavity, thus reducing the amount of shrinkage composite (Figure 11). Nevertheless, chemically cured GICs do not seal dentin perfectly, and they are difficult to handle due to their potential for rapid desiccation and cracking. Therefore, a light-cured GIC, if used as a build-up base (and particularly a dentin adhesive system) or a liner, may be more advantageous. To prevent these materials from adhering to the restorative composite, a thin layer of an insulating agent, such as a polyurethane isocyanate varnish (e.g., Dentin Protector, Ivoclar, Amherst, NY) may be applied over them (Figure 12). Following the application of these materials into the cavity, its margins have to be refinished to remove the varnish layer. Thereafter, a new bond is established on the freshly cut tooth surface in the marginal area. In this way, the gap formation is confined to the interior of the cavity, and the margins are perfectly adapted (Figure 13).

Selective bonding may improve sealing and marginal adaptation of large restorations with a high C-factor and those restored with an incremental technique. In addition, a distinctive advantage of the selective bonding is that it creates two independent penetration barriers within the restorative system. The first barrier is the margin of the restoration. In the event this barrier fails, a second barrier established (Figure 10). Selective bonding creates free surfaces within the cavity, thus reducing the C-factor of the restoration. One concern with the selective bonding technique is that dentin within the cavity remains unprotected, and is thus prone to postoperative sensitivity. To resolve this concern, a liner or base has to be introduced into the system. While this component has to
against penetration — formed by the adhesive base or the adhesive liner — is located inside of the cavity.

Separate bonding extends the concept of selective bonding by one step. In this case, the sealing of the cavity and the restoration are completely separated. The cavity is sealed by an adhesive system that does not adhere to or is insulated against the restorative material (Figure 14). In this manner, a microgap is formed in dentin and enamel along the entire interface between the sealed cavity and the restoration (Figures 15 and 16). This is particularly useful in amalgam substitutes, where one or two composite layers and a simple polymerization regimen are postulated for the restoration of large, box-shaped cavities. Under these parameters, a gap-free restoration with contemporary materials remains impossible.\(^{50}\) If, however, such a rapid and simple restorative procedure is required (eg, for economical reasons), separate bonding brings the separation into an area where it is not detrimental to the tooth (Figure 15).

A variation of the separate bonding technique is the secure bonding technique, where adhesion between the restorative material and the adhesive system is not completely eliminated, but it is weaker than the adhesion between the adhesive system and the tooth. In such a system, if the applied stresses exceed the bond strength, a partial separation will occur in the uncritical area between the adhesive layer and the restoration instead of the biologically critical tooth/adhesive interface.
Indications
Taking the previously mentioned principles into consideration, several clinical indications may be formulated. For amalgam substitutes, the separate bonding technique may be the procedure of choice. The advantage of this technique is a well-protected tooth structure despite a simple restorative technique in conventionally prepared, large, box-shaped cavities. The disadvantage is the presence of a microgap between the restorative material and the adhesive system. It may become discolored, thus compromising aesthetics and complicating clinical diagnosis of secondary caries. In addition, despite the application of an adhesive system, the restoration is non-adhesive and, as a consequence, requires macroretentive cavity preparation. This is in agreement with amalgam substitutes, however, as they target box-shaped, macroretentive cavities.

Total bonding may be indicated in all restorations with a small volume and/or a low C-factor and/or in need of a large adhesive surface for retention. This is the case for fissure sealants, preventive fissure sealings, small Class I and III composite restorations, Class IV restorations, wedge-shaped Class Vs, veneers, and large flat onlays. In these indications, total bonding results in optimal marginal adaptation, retention, and sealing. In addition, it is the simplest adhesive technique to perform.

Selective bonding is the procedure of choice for large Class I and III restorations and for Class II composite
fillings, inlays, and small onlays. It is also indicated for direct pulp capping with dentin adhesives, as it prevents the detachment of the adhesive system from the pulp opening caused by polymerization shrinkage of the restorative composite (Figure 17). Since it eliminates the internal stresses within the restorative system, it might also be the most effective solution for the restoration of cracked teeth. Used in combination with indirect restorations, selective bonding has the advantage of sealing the cavity dentin during provisionalization, thus avoiding postoperative sensitivity and bacterial penetration. This allows for the use of soft, resin-based provisional materials (e.g., Fermit, Veloce, Amherst, N.Y.; Clip, VoCa, San Antonio, TX).

While the secure bonding technique may improve the safety of any bonding procedure, even the best adhesive system and bonding procedure cannot provide a 100% guarantee of successful marginal adaptation. In instances where a gap is present, the secure bonding technique puts it between the adhesive system and the restoration, thus minimizing the risk of secondary caries for the tooth. Although this technique cannot be realized with contemporary restorative materials, it is appealing from the conceptual perspective, and might be the subject of future developments.

Conclusion
The practitioner should be aware that total bonding is not the only way of working with an adhesive system. According to the clinical situation, the best bonding technique should be selected to achieve the best combination of sealing, marginal adaptation, retention, and handling.

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References
CONTINUING EDUCATION  
(CE) EXERCISE NO. 25

To submit your CE Exercise answers, please use the answer sheet found within the CE Editorial Section of this issue and complete as follows:
1) Identify the article; 2) Place an X in the appropriate box for each question of each exercise; 3) Clip answer sheet from the page and mail it to the CE Department at Montage Media Corporation. For further instructions, please refer to the CE Editorial Section.

The 10 multiple choice Continuing Education (CE) questions for this exercise are based on the article "New perspectives on dentin adhesion—Differing methods of bonding" by Iva Krejci, DDS, PhD, and Minos Stavridakis, DDS, MS. This article is on Pages 727-732.

Learning Objectives:
This article describes various aesthetic adhesive modalities for application in selective, separate, and secure bonding. Upon reading this article and completing this exercise, the reader should:
• Understand the indications of selective and separate bonding procedures.
• Be conscious of bonding techniques for various restorative materials.

1. Which type of restoration relies exclusively on total bonding?
   a. Amalgam.
   b. Veneers.
   c. Full crown porcelain-fused-to-metal bridges.
   d. All of the above.

2. Which factors amplify the negative effects of composite polymerization shrinkage in a restoration?
   a. Large filler particles.
   b. Undercuts in the preparation.
   c. Large volume of the composite and a small surface area.
   d. A and B only.

3. Where can the free surfaces of a restoration be located?
   a. At the proximal surfaces.
   b. At the occlusal floor of the cavity.
   c. On the outer surface of the restoration.
   d. In all instances where the restorative material does not adhere to the tooth.

4. What is the configuration or C-factor?
   a. The ratio between the large and small filler particles.
   b. The ratio between the inner and outer surface of the restoration.
   c. The ratio between the free and bonded surface of the restoration.
   d. The ratio between the bonded and free surface of the restoration.

5. When shrinkage stresses become higher than bond strengths, delamination may occur and result in:
   a. Unprotected dentin tubules and postoperative sensitivity.
   b. Marginal discolorations, fissures, and recurrent caries.
   c. Loss of the interface between tooth and restoration, with loss of restoration.
   d. All of the above.

6. What causes the presence of "white margins" on a composite restoration?
   a. A filled adhesive system.
   b. Aging of the composite material.
   c. Marginal gaps or fractures in the enamel.
   d. Incorrect shade selection of the composite material.

7. Which restorative system most effectively tolerates the total bonding technique?
   a. Large Class I restoration.
   b. Proximal slot restoration.
   c. Large restoration with cervical margins located in enamel.
   d. Small volume of low shrinking composite, low C-factor, and a potent adhesive system.

8. What is one of the major advantages of the selective bonding technique?
   a. It is simple to use.
   b. It adheres only to the cervical margins.
   c. It provides the most monetary benefits for the clinician.
   d. It creates two independent penetration barriers within the restorative system.

9. What is separate bonding?
   a. Separation within the hybrid layer.
   b. Separation between an inlay and the luting cement.
   c. Separation between the bonding agent and tooth surface.
   d. Separation between the cavity and restoration by a microgap.

10. What are the indications of selective bonding?
    a. Class V restoration.
    b. There are no indications.
    c. Amalgam substitutes, crowns, and veneers.
    d. Class I and III restorations, Class II composite fillings, inlays, and small overlays.