Liners, Bases, and Cements
An In-Depth Review, Part 3

Authored by Randy Weiner, DMD

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LEARNING OBJECTIVES:
After reading this article, the individual will learn:
• To have a better understanding of glass ionomers and resins and how they work.
• To appropriately use glass ionomers and resin in clinical practice.

ABOUT THE AUTHORS

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Disclosure: In the past, Dr. Weiner has received honoraria for papers written on behalf of GC America and Heraeus Kulzer.

INTRODUCTION

Parts 1 and 2 of this series discussed the physical properties and clinical application of dental materials used as liners, bases, and cements. This article will discuss 2 other materials than can be used as a liner, base, and/or cement: the glass ionomer-based and resin-based materials.

GLASS IONOMERS

Originally developed in the 1970s, glass ionomers (GI) have 2 components, an acid soluble calcium fluoroaluminosilicate glass and an aqueous solution of polyacrylic acid (which is highly viscous) with itaconic, maleic, or tricarboxylic acid added to reduce viscosity. Tartaric acid might be added to improve handling properties, to increase working time, and reduce setting time. Some manufacturers add either zinc oxide or barium glass to provide radiopacity. ADA Specification No. 96 governs the properties of glass ionomers.

The fundamental principle behind GI as a dental material is a reaction between silica glass powder and polyacrylic acid liquid. The acid etches the surface of the glass particles, which releases Ca, Al, Na, and Fl into an aqueous medium. This is an acid-base reaction. Water serves as the re-action medium and ultimately makes the mix stronger.

In general, GI has a compressive strength comparable to zinc phosphate (ZOP), and slightly higher tensile strength than ZOP. The modulus of elasticity of GI is about half that of ZOP, meaning GI is less stiff.

GI is available in powder-liquid (P/L), paste-paste, and encapsulated versions. It is also available in chemical-cured and light-cured formulations. The P/L varieties are usually less expensive; the paste-paste products assure the clinician of the proper base/catalyst amounts; and the advantages of capsules include convenience, consistent P/L ratio, and easy cleanup. Also, there is no need for hand mixing, which will decrease working time. The setting of encapsulated products is accelerated due to the energy generated during trituration.

One advantage of GI as a dental material is its ability to bond with the tooth. Adhesion is via hydrogen bonding of the carboxyl groups of the polyacids with the calcium in the apatite of the enamel and dentin. In addition, micromechanical penetration of the GI into the tooth structure has been demonstrated. Another significant factor is the coefficient of thermal expansion (CTE) of GI. CTE of GI is similar to tooth structure, especially dentin. This helps reduce the potential for microleakage and postoperative sensitivity. Another important characteristic of GI is the release of fluoride over time. GI cements also absorb fluoride at the restoration margin. Although the amount that is released/absorbed has not been fully defined, it has been shown that fluoride release occurs initially in large amounts, then continues at a declining rate for periods of one year or longer. When replenishing the fluoride, a neutral fluoride should be used since an acidic

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fluoride may dissolve the surface of the GI. There are several methods for replenishing fluoride to GI cements: toothpastes, topical application, and gels. Use of a fluoride gel is the most effective method.

It has been suggested that caries protection by fluoride ceases when fluoride intake or replenishment is terminated. The fluoride released from GI aids in the formation of fluorohydroxyapatite in the adjacent tooth structure. This will not prevent recurrent caries but will render the adjacent tooth structure more resistant to demineralization. Studies confirm that the fluoride ions that are released do inhibit secondary caries. Also, studies demonstrate that fluoride is toxic for microorganisms associated with caries. GI has been shown to have a greater antibacterial effect than calcium hydroxide (CaOH).

Microbial plaque will always be present in the mouth, especially around restoration margins. Supragingival plaque is acidic in nature. Carey and others have shown that initially more fluoride is released from GI in an acidic environment compared to a neutral one. Davidovich and colleagues have shown that GI and zinc oxide eugenol (ZOE) products inhibited bacterial growth, and this effect lasted for at least one week.

To promote adhesion of GI material to the tooth, surfaces should be cleaned with either pumice or phosphoric or polyacrylic acid, followed by rinsing with water. Additionally, the mix should flow enough to reduce the possibility of gap formation and allow complete seating of the restoration. The mix should be used while still glossy, as this indicates unreacted polyacid on the surface. This residual acid is critical for bonding to the tooth. If the surface looks dull then there is inadequate free acid for bonding.

Some GI formulations include a polymerizable monomer and a cross-linking agent. These are known as resin modified glass ionomers (also resin reinforced or hybrid ionomers). These generally have a longer working time and are less sensitive to moisture contamination than are conventional GI. With these versions, the physical properties are dependent on the depth of cure. The set reaction involves light activation that causes the polymerizable components to cross link or form a gel, and allows for self-curing of the polymerizable groups. Light cured versions can be hardened more quickly than self-cured materials.

Glass Ionomer as Liners
Use of GI tends to reduce the probability of marginal gap formation, especially at the gingival margins. The term “sandwich technique” refers to the use of a GI to replace the dentin when a composite replaces the enamel. GI will absorb moisture from the dentin and will expand. This expansion in volume will serve to compensate for the polymerization shrinkage of the composite. Further, when GI is applied to the cavosurface margin, microleakage of class II resin restorations is reduced. When used in this fashion the GI material can be placed in contact with fluoride-containing products.

When used as a liner, resin reinforced glass ionomer (RRGI) was better at preventing microleakage than a dentin bonding agent (DBA) or a DBA in combination with a flowable composite, flowable compomer, or self-cured composite. Further, it has been suggested that RRGI has a chemical bond to sclerotic dentin that is stronger than the bond that results from etching dentin followed by a DBA. Alex states that the utilization of a RRGI as a liner is the easiest and most predictable way to manage microleakage.

Glass Ionomer as Bases
There is evidence that GI, when placed over decalcified dentin in close proximity to the pulp, can promote remineralization, even in areas of active caries. For this reason, clinicians can use GI as a base in areas where deep caries has been excavated, and before the final restorative material is placed. Sealing the preparation in this manner results in the eventual death of the bacteria in the lesion, and the pulp may begin the repair process. Also, GI can bond without etching of the tooth structure or removal of the smear layer.

Glass Ionomer as Cements
The film thickness of GI is similar to or less than ZOP. The RRGI versions are reported to be stronger, less water-soluble (due to the cross linking of the resin component) and more adherent to the tooth than conventional GI. RRGI is also more resistant to dissolution and disintegration. Although GI can be finished and polished immediately after the set, the restorations remain moisture sensitive. It is recommended that a resin adhesive be used as a surface
It has been shown that light-cured GI absorbs water (from saliva and dentinal fluid) over time, causing swelling and a reduction in strength and stiffness. This absorption of water can take up to 18 months to occur and can be beneficial (compensates for polymerization shrinkage of composite resin). However, when used as a cement this expansion can cause fracture of all-porcelain restorations even 6 months after placement. Irie and Suzuki have shown that the bond strength of GI to enamel and dentin, and the flexural strength of GI, increase after storage in water. Therefore, the marginal seal of GI may not only be improved due to hygroscopic expansion but may also exhibit greater bond strength.

In a study that compared ZOP, zinc polycarboxylate (ZPC), and GI with respect to solubility, disks of the materials were placed in the flanges of mandibular dentures. The results showed that ZOP and ZPC demonstrated approximately equal solubility, but significantly more solubility than GI. Stutes and Duke stated that if a luting cement were to inhibit the colonization of caries-producing microorganisms at the marginal areas for a significant period, restorative longevity may be improved (see Table).

### RESINS

Resin-based liners, bases, and cements have benefited from the general advances in composite resin material science (improved working properties, acid etch technique, enamel and dentin bonding). ADA Specification No. 27 governs properties for polymer-based filling, restorative, and luting agents. These materials can be grouped into one of 3 classes, based on the method of curing.

The first class of materials consists of those that can be self-cured and are available in powder/liquid or paste/paste delivery systems. These are slow curing, which allows for an increase in the working time. The initiator is a peroxideamine. Class 2 materials are light-cured versions with a single component. These have extended working time but are sensitive to ambient light. Class 3 materials are dual-cured products. They cure rapidly with light, and then continue to cure to gain strength over time (due to the self-curing property).

Since there are different types of resins (unfilled and filled), these will be discussed separately.

### Resin-Liner: Primer/Unfilled Resin

The newest generation of resin materials includes the use of a dentin primer. It is the primer or the unfilled resin (for those products that have no primer) that is actually in contact with the preparation, not the filled material. A primer is essentially a hydrophilic, low-viscosity liquid that promotes the bonding of a resin to the tooth. The primer contains either ether (which...
dries quickly), alcohol (additional drying time), or water (even longer drying time). The primer is applied to the dentin, which contains dentinal fluid. The solvent combines with the water in the dentin and evaporates, leaving the resin component (sixth and seventh generation materials only). The hydrophilic property of the primer counteracts the hydrophobic nature of the resin, and therefore allows greater wetting of the preparation by the resin.

When these materials are placed on the prepared tooth, they form what is called a hybrid layer. The hybrid layer or zone, with occluded tubules, results in a reduction in dentin permeability. Therefore, these materials are essentially a liner. The primer also increases mechanical retention by forming a layer of resin-infiltrated dentin. This occurs after the acidic primer dissolves the smear layer, leaving the tubules open so that the adhesive portion can diffuse into the dentin.

Acetone-based and water-based bonding systems were compared for their effects on the hybrid layer and resin tag formation. It was concluded that there are significant differences in the micromorphology of the hybrid layers produced by acetone-based and water-based systems. The acetone-(solvent)based systems provide a thick, continuous hybrid layer with well-formed resin tags that are closely adherent to tubuli walls. When the water-based systems were used the hybrid layer was thinner and some tubuli were sealed to a lesser degree, which may allow more microleakage.

The sixth and seventh generation materials are considered self-etching because they are acidic in nature (carboxylic acid). In fact, they can irritate the skin. Additionally, these self etching products reportedly etch the enamel less deeply and result in restorations that are less retentive than conventional phosphoric acid etching. Therefore, it would be best to etch the enamel (not dentin) using phosphoric acid prior to use of the self-etching agent.

There is contradictory evidence with respect to the compatibility of self-etching systems with resin cements. Some investigators believe that this incompatibility is due to the acidity of the single bottle primer-adhesive. One study compares microleakage of etch-and-rinse systems versus self-etching adhesive systems. Etch-and-rinse products were associated with less microleakage than the self-etching adhesives. The authors concluded that etch-and-rinse systems are better than self-etching adhesives for preventing microleakage.

The newer adhesives (seventh generation materials) are simplified systems, but do not produce improved results compared to older total-etch, 2-bottle bonding agents. This is true for both experienced and inexperienced clinicians.

When using a self-etching system, the clinician must be certain that the tooth is free of water, saliva, blood, and any other source of moisture. If any moisture is present, the self-etching primer will be washed off the preparation, which leaves the tubules open. Open tubules could result in tooth sensitivity. A 3-year clinical study of composite restorations comparing the depth of the preparation, cavity liner, and postoperative sensitivity found that postoperative sensitivity was not related to the absence of protective layers (liner), but increased with the depth of the cavity. Chemical-cured materials had a high incidence of postoperative sensitivity. The light-cured materials (self-etching/self-priming) were associated with less postoperative sensitivity.

The phrase “technique sensitive” is frequently used, and can be related to the number of steps involved in placing a material. Further, sometimes there is confusion with respect to how dry a preparation should be prior to placing the primer. The deeper the preparation, the more moisture there is in the dentin, thus reducing the bond strength. Bonding to deep dentin is sensitive to moisture contamination from fluid within the dentin. Tay and Pashley recommend overdrying the dentin, especially in deep preparations. Occlusion of the dentinal tubules would prevent this fluid contamination and improve bonding. Sadek, et al conducted a study with an experimental hydrophobic adhesive. They found that applying oxalate or poly (glutamic acid) acid-modified diluted ceramicrete (PADC) to the preparation prior to the adhesive resulted in reduced dentin permeability, prevented fluid contamination, and improved bond strength. Therefore, the use of tubular occluding agents optimized the bonding of hydrophobic resins to dentin.

Burgess and Cakir stated that when single bottle self-etching bonding agents are polymerized, water is trapped in the hybrid layer and slowly evaporates. Bubbles formed from water evaporated from the bonding agent and in the tubules slowly coalesce, making the hybrid layer permeable. The fluid from the dentin moves through this permeable layer, forming channels. Over-drying the bonding agent helps
reduce the residual water in the hybrid layer and helps to preserve the bond strength. Any water retained in the bonding agent: 1. inhibits polymerization of the bonding agent, 2. produces channels, which increases porosity, and 3. softens the resin. This causes the adhesive to weaken with time and reduces bond strength. Increasing the curing time makes adhesives less permeable and more durable.

It has been suggested that the bond strength of resins to sclerotic dentin was reduced due to tubule occlusion by mineral salts, which prevented resin tag formation. Further, it was shown that the dentin had a hyper-mineralized surface that resisted acid etching (total etch and self etch), which prevented hybridization and therefore lowered the bond strength. However, other investigators have shown the opposite. Kusunoki, et al evaluated the effect of a dentin bonding system on sclerotic dentin compared to normal dentin. They concluded that sclerotic dentin had an advantage over normal dentin with regard to adaptation of the resin to the tooth structure. They concluded that sclerotic dentin should be preserved and not exposed to acid etching.

Because self-etching agents evaporate after being placed on the tooth, they are not stable when exposed to air. These products should be sealed in their containers between use, and should be refrigerated prior to use. Miyazaki, et al investigated the influence of temperature and humidity on bond strength of dentin bonding agents. They found that dentin bond strength decreased with increasing humidity but was not influenced by temperature (this may be another reason to use a rubber dam, as exhaled air is humid). However, Sundfeld, et al did not corroborate these findings. They found that to obtain better and longer resin tags with self-etching adhesive systems, the material should not be used immediately after removal from the refrigerator. It should be allowed to warm to room temperature.

Clinicians should keep in mind that primers have a very low film thickness, whereas unfilled resins have a greater film thickness. Further, unfilled materials can “pool” prior to setting. These pools will (1) make it harder to seat an indirect restoration, and (2) appear as a radiolucent area on a radiograph, which may be misinterpreted as recurrent caries. Further, thick layers of unfilled resin are usually undesirable because of a poor match of the coefficient of expansion and high hydroscopic expansion relative to composites (see Table).

**Resin-Liner: Flowable**

Another type of resin material promoted for use as a cavity liner is the flowable resin. Flowable resins are essentially composites with a reduced filler content, which provides a consistency that allows the material to flow readily and spread uniformly, reducing polymerization shrinkage and improving adaptation to the cavity preparation. These materials are promoted as a liner, but the primer/bonding agent needs to be placed first.

These materials reduce micro-leakage due to their ability to flex with the tooth to maintain the seal. This allows the material to better adapt to the preparation. The flowable resin also acts as a stress-absorbing layer. Even though these materials have a 4% to 5% volume shrinkage associated with polymerization, the net result is a decrease in gap formation and a reduction in microleakage, secondary caries, and pulpal inflammation.

However, Christensen notes that these materials are not intended to be used as a liner. He recommends using a fluoride releasing product instead. Some flowable resins contain fluoride but the amount that is released is very low and decreases during the first 3 weeks.

Nevertheless, many clinicians use flowable resins as liners, but prior to using the product they need to consider the radiopacity of the material. A liner that is not more radiopaque than the dentin could lead the clinician to mistake the radiolucent resin for recurrent decay (see Table).

**Resin-Base**

Resins are usually not considered to be a base, but are core buildup materials, and are marketed as such. However, they are also applied after a primer and bonding agent. These resins fit the definition of a base, specifically because they can be shaped and contoured immediately after being placed. Further, they act as a temperature buffer, and either a direct or indirect restoration can be placed above these materials.

If a resin base is placed under a metallic restoration, then the color of that composite material is not important. In the event there is a need to restore that tooth again, the colored resin base would easily allow the clinician to differentiate the base from the dentin (see Table).
Resin-Cement

Resins used as cements are essentially flowable composite resins. They can be classified as either a temporary or final cement. Adhesive resin cements are composed of acrylic or diacrylic resins with adhesive monomers that bond to metal substrates. They are available in self-, light-, or dual-cured formulations.

As mentioned in Part 1 of this series, the names of products can be confusing with respect to resin cements. Products can be categorized into one of 5 types: (1) Bonded restorations: all-ceramic and indirect composite restorations that are typically bonded with resin cement. (2) Luted restorations: metal, ceramo-metal, and high strength ceramic restorations that are mechanically retained (luted) with cement that does not chemically bond to tooth structure. (3) Adhesive resin cements: bond to metal substrates; may require the use of a separate primer for bonding. (4) Self-adhesive resin cements: cements with adhesive components that eliminate the need for separate primers. (5) Aesthetic resin cements: tooth-colored or translucent cement based on diacrylate resin that requires a bonding agent and separate primers for different substrates (eg, silane).

Resin cements are available in different delivery systems: auto-dispensed syringes, automix syringes, capsules, paste-paste systems, and powder-liquid systems. They are ideal for tooth-colored restorations. Generally they are available in many shades and have high strength (greater than RRGI). These cements do not expand, as do RRGIs, so there is no threat of fracture of the restoration due to such expansion. The primers and bonding agent associated with these systems serve to increase the bond strength of the resin cement.

There are 2 types of resin cements. (1). Those that require a separate self-etching bonding agent (eg, Panavia [Kuraray America], Multi-link [Ivoclar Vivadent]). With these cements the self-etching agent, usually a 2-component liquid, is applied prior to seating the restoration with resin cement. Only a limited number of shades are available with these products. (2). Cements that contain a self-etching agent (eg, RelyX Unicem [3M ESPE], GCEM [GC America]). These are easier to use, are dual cured, and are not associated with postoperative sensitivity. Long-term research on bond strength is not available, and they do not release fluoride. Therefore these materials should not be used in high caries risk patients.

Luting agents should be radiopaque. It is best if the cement is more radiopaque than the dentin. This allows the clinician to diagnose recurrent caries, and detect open margins and any residual material (overhangs).

A number of manufacturers call their dual-cured cements “all-purpose” luting agents. The problem with this designation is that not all products meet this description. The choice of a dual-polymerized cement should be based on its intended use because not all products polymerize adequately in every clinical situation. In fact, these systems achieve a lower degree of conversion and have a shorter shelf life. The degree of conversion refers to the percentage of carbon double bonds that disappear as the material polymerizes.

A recent study by Pace, et al concluded that initially all resin cements are not comparable in terms of physical properties, but that these differences diminished after aging in water. In contrast, another report concluded that dual-cured cements demonstrated the best combination of mechanical and physical properties. However, these materials must be photopolymerized to achieve the greatest strength and rigidity. The authors suggest that there is a reduction in mechanical properties in situations where light cannot reach all regions of the material. This reduction in strength reflects reduced polymerization.

Therefore, dual-cure cements that are also light-cured will have the most desirable properties. Clinically, dentists must be cautious about the potential for microleakage immediately after cementation of an indirect restoration with a self-curing resin cement. This may result in washout of the uncured cement, which could lead to an open margin. Further, with respect to microleakage, a comparison between acid-base cements and a resin cement indicated that the resin cement exhibited significantly less microleakage than the other luting agents.

Christensen notes that total-etch bonding agents do not totally eliminate postoperative sensitivity. Self-etching liquids applied before the use of a resin cement are more predictable but may still result in some postoperative
sensitivity. To eliminate this problem when using a resin cement, a resin cement that incorporates a self-etching agent should be used. Christensen\(^\text{92}\) notes that these products should be used for reducing postoperative sensitivity and not for retention (see Table).

**CONCLUSION**

Glass ionomer and resins are the last 2 types of materials that are discussed in this series. The literature focusing on these materials is expanding, and it is incumbent on all clinicians to keep abreast of the new research on these materials.

The concluding part of this series will review cementation techniques, cavity preparation, and other relevant clinical information pertaining to the use of liners, bases, and cements.

**REFERENCES**


52. Christensen GJ. Bonding to dentin and enamel:
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POST EXAMINATION QUESTIONS

1. Glass ionomers work because of a reaction between the silica glass powder and the polyacrylic acid. Calcium and fluoride are some of the ions released.
   a. Both statements are true.
   b. First statement is true, second statement is false.
   c. First statement is false, second statement is true.
   d. Both statements are false.

2. The compressive strength of glass ionomer is comparable to zinc phosphate. The modulus of elasticity of glass ionomer is about half of zinc phosphate.
   a. Both statements are true.
   b. First statement is true, second statement is false.
   c. First statement is false, second statement is true.
   d. Both statements are false.

3. Not only do glass ionomers release fluoride they also absorb it. The release occurs initially in large amounts but then declines for about 1 year.
   a. Both statements are true.
   b. First statement is true, second statement is false.
   c. First statement is false, second statement is true.
   d. Both statements are false.

4. Method(s) for replenishing fluoride in glass ionomers is/are:
   a. Tooth paste.
   b. Topical fluoride.
   c. Fluoride gels.
   d. All of the above.

5. Glass ionomer can absorb moisture and will expand. This expansion can lead to an increase in microleakage.
   a. Both statements are true.
   b. First statement is true, second statement is false.
   c. First statement is false, second statement is true.
   d. Both statements are false.

6. Resin reinforced versions of glass ionomers are not as strong as conventional formulations. They are also less soluble due to cross-linking of the resin component.
   a. Both statements are true.
   b. First statement is true, second statement is false.
   c. First statement is false, second statement is true.
   d. Both statements are false.

7. As a cavity liner, resin reinforced glass ionomers are better at preventing microleakage than DBAs. RRGI has a chemical bond to sclerotic dentin that is stronger than the bond of DBAs to etched dentin.
   a. Both statements are true.
   b. First statement is true, second statement is false.
   c. First statement is false, second statement is true.
   d. Both statements are false.
8. To promote adhesion, the tooth should be cleaned with:
   a. slurry of pumice.
   b. phosphoric or polyacrylic acid.
   c. both of the above.
   d. none of the above.

9. Class 1 resins are also known as self-cured materials. Class 2 products are chemical-cured materials.
   a. Both statements are true.
   b. First statement is true, second statement is false.
   c. First statement is false, second statement is true.
   d. Both statements are false.

10. The dentin primer is a hydrophilic, low-viscosity liquid. It is either ether-, alcohol-, or water-based.
    a. Both statements are true.
    b. First statement is true, second statement is false.
    c. First statement is false, second statement is true.
    d. Both statements are false.

11. After a cavity preparation the tubules are open and placement of a primer will occlude the tubules.
    Therefore a primer is essentially a liner.
    a. Both statements are true.
    b. First statement is true, second statement is false.
    c. First statement is false, second statement is true.
    d. Both statements are false.

12. Dentin bonding agents can pool after placement and prior to curing. This can make it:
    a. difficult to seat a restoration.
    b. appear as a radiolucent area on a radiograph.
    c. both a and b.
    d. neither a nor b.

13. Flowable resins:
    a. are essentially composites with a reduced filler content.
    b. allow for improved adaptation of the restoration to the cavity preparation.
    c. both a and b.
    d. neither a nor b.

14. There are different types of resin cements. They include:
    a. adhesive resin cements.
    b. aesthetic resin cements.
    c. self-adhesive resin cements.
    d. all of the above.

15. Resin cements are available in a number of different delivery systems. They are ideal for tooth-colored restorations and are available in many shades.
    a. Both statements are true.
    b. First statement is true, second statement is false.
    c. First statement is false, second statement is true.
    d. Both statements are false.

16. An ideal luting agent should be radiopaque. This allows for the detection of open margins, recurrent decay, and flash.
    a. Both statements are true.
    b. First statement is true, second statement is false.
    c. First statement is false, second statement is true.
    d. Both statements are false.
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6. a  b  c  d  
7. a  b  c  d  
8. a  b  c  d  
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11. a  b  c  d  
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