Liners, Bases, and Cements
An In-Depth Review, Part 1

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LEARNING OBJECTIVES:
After reading this article, the individual will learn:

• the definition of liners, bases, and cements, and
• clinical indications for liners, bases, and cements.

ABOUT THE AUTHORS

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INTRODUCTION

The restorative dentist must make decisions on a daily basis regarding which liner and/or base to use under a restoration, or which cement to use when placing an indirect restoration. Clinicians’ knowledge of this subject must be current, as manufacturers regularly introduce new products and techniques.

To make matters even more complex, in some instances the name of the product can be misleading. Some products have the words “lining cement” in the name, even though the product is not designed to be used as a cement. Others are called cements (specifically when referring to glass ionomers) even when the product is intended to be used as a restorative material, not as a luting agent.

In an attempt to reduce or eliminate this uncertainty, it has been suggested that the use of liners and bases be reassessed.1 It has been stated that when dentists are going to make a change, they should do so to improve the clinical outcome, and that the process of choosing a new material includes reading the literature (including the product instructions) and discussion with colleagues.2 This article will discuss the definition of liners, bases, and cements; review their clinical applications, mechanical properties, and biocompatibility; and discuss the principles of adhesion and the use of fluoride in these materials. Parts 2 and 3 in this series will discuss specific types of materials and their use as liners, bases, or cements, and Part 4 will discuss cementation technique for different types of restorations, cavity preparation designs, curing lights, and other relevant clinical information.

DEFINITIONS

The definitions of liners, bases, and cements can be confusing to clinicians. The following definitions are from dental materials textbooks.

Definition of a Liner

Craig and Powers3 stated that cavity liners are suspensions of calcium hydroxide in an organic liquid.

Figure. Physical properties determine how materials respond to changes in their environment.

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When the solvent evaporates, the remaining film on the tooth surface functions as the liner. Ferracane uses a broad definition, defining a liner as a material that is applied in a thin layer to seal the dentin on the floor and walls of the cavity from the influx of bacteria and irritants from restorative procedures. As an example of the confusion with nomenclature, Phillip’s Science of Dental Materials (Anusavice) defines cavity liners as a thin layer of “cement” used for protection of the pulp.

**Definition of a Base**

Anusavice stated that a base is a layer of insulating, sometimes medicated, cement, placed in the deep portion of the tooth preparation to protect the pulpal tissue from thermal and chemical injury. Ferracane concurs, and adds that bases are applied in thick layers and must be strong enough to support a restorative material during its placement and function, and should offer thermal and electrical protection (from galvanic activity) to the pulp. Craig and Powers categorize bases into 2 groups. The first is low-strength bases of CaOH or ZOE cements, which are referred to as liners; the second is high-strength bases, which have the same description as provided by Ferracane.

**Definition of a Cement**

O’Brien does not provide a specific definition or description of a liner or a base, but concludes that cements are the most important materials in clinical dentistry because of their application as luting agents, cavity liners and bases to protect the pulp, and restorative materials. Craig and Powers note that cements have 2 primary purposes: as a restorative filling material during its placement and function, and to retain restorations or appliances in a fixed position in the mouth. Ferracane states that the most obvious use for a cement is for permanently retaining castings to tooth structure. Anusavice combines these definitions and writes that a cement is a substance that hardens to act as a base, liner, filling material, or adhesive to bind devices and prostheses to tooth structure or each other.

It is apparent that even textbooks on dental materials do not provide clear, conclusive definitions of liners, bases, or cements. For clarity, the following definitions and descriptions should be useful to clinicians.

A liner will be defined as a thin layer of material (0.5 mm) placed on the surface of the tooth preparation that in part protects the tooth from the restorative material, intraoral fluids, and ultimately from the outside environment. Additionally, liners usually do not have sufficient thickness, hardness, or strength to be used alone in a deep cavity.

A base will be defined as a material that is used to replace missing dentin, and, therefore, is thicker than a liner. It should be able to withstand the forces of condensation immediately after being placed. It is used under a permanent restoration to encourage the recovery of the injured pulp and to protect the pulp from thermal and galvanic shock, as well as mechanical trauma. Additionally, these materials can be shaped and contoured prior to placement of the final restoration.

A cement will be defined as a material that is used to lute together an indirect restoration and the prepared tooth. It may also possess some of the therapeutic characteristics of liners and bases.

**WHY DO WE NEED THESE MATERIALS?**

For years it was taught that the restorative materials that clinicians place in the mouth were, to some degree, harmful to the tooth, specifically the pulp. These harmful or toxic effects could cause or lead to postoperative sensitivity. If this were true, then clinicians needed something placed between the restoration and the tooth to protect or buffer the tooth. The result would be the elimination of postoperative sensitivity.

This theory has been modified and expanded over the years. It is now believed that postoperative sensitivity is not caused by the restoration but by bacteria and their byproducts. Bacteria are present in saliva and gain access to the tooth at the margin of the restoration where there is a microscopic space between the restoration and the tooth surface. This is known as microleakage and occurs through capillary action. Gordan, et al define microleakage as the marginal permeability to bacterial, chemical, and molecular invasion at the interface between the teeth and restorative materials. Therefore, microleakage can also be defined as the flow of oral fluid and bacteria into the microscopic gap where a prepared tooth surface and restorative material meet.
Causes of microleakage include differences in thermal expansion of restorative material and teeth, polymerization shrinkage, effects of finishing and polishing, orientation of enamel prisms, application methods, and cavity configuration. Murray, et al9 stated that the most frequent and potentially serious postoperative complications can emanate from bacterial microleakage. These complications can include postoperative sensitivity, marginal discoloration, recurrent caries, pulpal inflammation, pulpal necrosis, periodontal disease, and eventual need for endodontic therapy.

Bacterial contamination is not the only theory that has been proposed to account for postoperative sensitivity. Brannstrom10 has postulated that postoperative sensitivity is caused by fluid movement in the gap between the tooth and the restoration. This movement of fluid causes changes in the osmotic pressure under the restoration and is known as the hydrodynamic theory. According to this theory, the pulp chamber is under pressure, and this pressure forces dentinal fluid outward (in a coronal direction). The fluid surrounds the odontoblasts, and the enamel usually seals the end of the dentinal tubule. Any opening in the enamel, whether by caries, trauma (fracture), or a dental procedure allows the fluid to escape the tubule. These openings also allow bacteria, chemicals, and other substrates to diffuse inward along the tubule (even against the outward flow) and into the pulp. This movement of fluid causes the nerve fibers to be stimulated, resulting in sensitivity.

Camps, et al11 performed a comparative study to determine the importance of bacteria on the cavity walls, the remaining dentin thickness, and the type of restorative material. They concluded that the presence of bacteria on the cavity walls is the main factor influencing the pulpal reaction under restorative materials. If bacteria are present, then the type of restorative material is not important. Yoshiyama, et al12 found that sealing dentinal tubules completely renders the dentin insensitive and can eliminate postoperative sensitivity. Therefore, liners, bases, and cements are used to reduce, if not eliminate, microleakage and the associated problems. It should be noted that in contrast to the studies cited above, one study concluded that the use of a liner and a base resulted in an increase in microleakage compared to a tooth restored without the use of a liner or base.13

Postoperative sensitivity has causes other than microleakage. One is the interaction or contact of dissimilar metals. In dentistry, this refers to 2 adjacent restorations made from different metals (usually gold and silver amalgam), and is known as galvanic shock. Desiccation of the tooth preparation has also been suggested as a possible cause of postoperative sensitivity. An additional possible cause is due to thermal conductivity of the restorative material. Metallic restorations (gold and silver amalgam) retain heat and cold longer than nonmetallic restorations. Patients can also experience pain under restorations when a gap is present between the cavity preparation and the inner surface of the restoration. When a person bites down on a restoration over this gap, the fluid in the gap is then forced into the tubules and toward the pulp, eliciting pain. Therefore, the placement of a material between the tooth and restoration could prevent this.

PREVENTING MICROLEAKAGE

Microleakage can be prevented with a proper restorative technique. Recently, it has been reported that the use of cavity cleansers such as chlorhexidine (CHX) reduces or eliminates bacteria that remain in the tooth preparation. Strupp14 suggests using successive dentin scrubs with chlorhexidine gluconate 4%, Tubulicid Red (Global Dental Products), and sodium hypochlorite to kill bacteria and remove debris from the dentin surface.

CHX, a protease inhibitor, has also been shown to stabilize the resin-dentin bond. A study by Carrilho, et al15 compared teeth treated with CHX to untreated teeth in regard to degradation of the resin-dentin bond. After 14 months in the oral cavity, bond strength on untreated teeth was significantly reduced compared to CHX-treated preparations.

Isolation of the operative field is essential. The best way to accomplish this is with the use of a properly placed rubber dam. This means the edges should be inverted and no saliva or blood should be allowed to accumulate around the tooth/teeth being treated. Additionally, margins need to be sealed as best as possible. They also need to be as smooth as possible. A restoration with a rough surface or a rough margin makes it more difficult for the patient to clean. This could lead to plaque accumulation and demineralization of the tooth at that margin, resulting in recurrent caries.
PHYSICAL PROPERTIES

Physical properties determine how materials respond to changes in their environment. A brief review of physical properties is important. This knowledge will enable clinicians to make an informed decision when choosing dental materials.

Stress

When a force is exerted on a material, the resistance that the material has against this force is equal to, and in the opposite direction of, the initial force. This is called stress, and there are 3 kinds:

3 Tension. Tension occurs when a body is subjected to 2 sets of forces directed away from each other along a straight line. Also known as tensile force, this force tends to stretch or elongate the body.

Compression. Compression occurs when 2 forces are directed toward each other; this force is referred to as compressive. A force is placed on a body and tends either to compress or shorten it.

Shear. Shear stress occurs when 2 sets of forces are directed parallel to each other. This occurs when a body is twisted or slides over another body.

Elastic Modulus (Modulus of Elasticity)

Elastic modulus is the measure of elasticity or stiffness of a material. This is a good predictor of a material’s ability to resist bending or change in shape. A stiff material will have a high modulus, whereas a flexible material will have a low modulus.

Hardness

Hardness refers to a material’s resistance to permanent surface indentation or penetration. Methods to measure hardness include the following:

- Brinnell (BHN): Uses a small metallic ball of about 1.6 mm diameter
- Knoop (KHN): Uses a diamond indenting tool with a pyramid shape.
- Vickers (VHN): Uses a 136° diamond pyramid tip.
- Barcol: Used to study the depth of cure of composites; uses a 1mm spring-loaded diamond-tipped needle. No indentation is 100; the reading decreases as the needle penetrates the material.

Wear

Wear is defined as the loss of material as a result of the contact of 2 or more materials. Wear does not involve liners or bases. It is relevant to cements only if the restoration cement margin is in occlusal contact.

Viscosity

Viscosity is the resistance of a liquid to flow. Highly viscous materials flow slowly. Dental materials can have different viscosities depending on their intended use. A thinner mix (one with a low viscosity) is better for a liner or cement.

Coefficient of Thermal Expansion

Coefficient of thermal expansion is defined as the change in length per original unit of a material when its temperature is raised. This property is important when attaching or bonding different materials together.

Water Absorption

Water absorption is the measure of the penetration of water into the structure of a material. Water absorption by polymers can help offset the effects of processing or polymerization shrinkage, but can also have detrimental effects such as discoloration.

Setting Time

Setting time is the elapsed time from the start of mixing to the point at which the mixture reaches a desired hardness or consistency. The setting time does not indicate the completion of the reaction, which may continue for a longer period of time.

BIOCOMPATIBILITY

By definition, biocompatibility refers to a material’s ability to elicit an appropriate biological response when in contact with the body. In other words, it is the effect a material has on the tissue it contacts. When a foreign material is placed in the body it creates an interface that is not normally present. According to Anusavice, this interface is not static, but is dynamic. These interactions determine both how the body will react to the foreign material and how that material will resist
degradation. The host condition will affect this interaction. Adverse responses to a foreign material can be categorized as toxic, inflammatory, allergic, and mutagenic reactions.

Toxic reactions or the toxicity of the material refers to the release of substances from the material that affect the patient. Inflammation is the biological response to this toxicity and is characterized by reactions of cells and molecules. The association of dental materials with an inflammatory reaction is especially important because pulpal and periodontal diseases are inflammatory responses. Both have aspects of acute and chronic inflammation.

An allergic response is the body’s disproportional reaction to a specific foreign material. Mutagenic reactions occur when the components of the material alter the base-pair sequences of the DNA in the cell, possibly leading to malignancy. Clinicians should be aware that the effects of these materials can be seen in areas of the body other than the oral cavity. These materials can be ingested during placement, inhaled, can enter the body through the apical foramen of the tooth, and even be absorbed through the mucosa.

The pulp has the capacity to produce additional dentin as a result of caries, cavity preparation, or in response to material placement. This new tissue is known as reparative dentin. Some materials promote this replacement, while others can harm the pulp. The effect of adhesive restorative systems on the human pulp, and the response of the pulpal-dentin complex (biocompatibility) depend on the remaining dentin thickness.

Bisphenol-A (BPA) is associated with the manufacture of some plastics, including composites, and there have been some safety concerns about BPA. Although lab tests have shown that BPA has the same effect as estrogen, none of these effects have been observed in humans. Due to the action of salivary enzymes on sealants and composites, there may be some low-level exposure to BPA. The ADA is not currently expressing any concerns regarding BPA exposure.

ADHESION

Every dental restoration is retained via mechanisms such as irregularities of the prepared tooth and/or the restoration, undercuts in the preparation, length of the preparation, and/or the effects of the luting agent. Since a number of liners, bases, and cements are retained via the mechanism of adhesion, a review of the principles of adhesion is in order.

Adhesion is defined as the force of attraction between the molecules or atoms on 2 different surfaces as they are brought into contact. When the molecules are of the same kind, it is referred to as cohesion. Adhesion requires both a substrate, known as the adherend, and the material producing the adhesion, called the adhesive or adhesive layer. The components used to form the adhesive layer are referred to as a bonding agent.

The fundamental mechanism for all dental restorative adhesive systems is the same. An acid removes minerals from both the enamel and the dentin. In the spaces created by demineralization, resin monomers are introduced and polymerized. In both the enamel and dentin, sealing, bonding, and retention are facilitated by micromechanical retention into the microporosities created during the bonding process.

Failure of the bond can occur when formation of cracks along the interface allows moisture into the created spaces. These cracks will grow over time because of the stress that forms not only within the tooth but within the adhesive material. This can lead to gap formation and recurrent caries, stained margins, and loss of the restoration. There are 2 types of bond failure: the first, within the substrate, is referred to as cohesive failure; the second, between the substrate and adhesive, is called adhesive failure.

To reduce the chance of bond failure, the formation of an optimally bonded interface requires that all surfaces be clean, the adhesive wets the adherend, the adhesive intimately adapts to the adherend (without any gaps, interference from other materials, or obstructions), the interface includes sufficient strength to resist (intraoral) forces of debonding, and the adhesive is well-cured.

Adhesion is a critical concept for clinical dentistry. The stronger the adhesion, the greater the chance that the restoration will be retained on the tooth. Second, a tooth with minimal tooth structure remaining after the preparation, which is not an ideal preparation, will require the use of a strong adhesive to keep the restoration in place. Lastly, strong adhesion of the material to the tooth will reduce microleakage.
It is well documented that fluoride has anticariogenic properties, and the formation of secondary caries is inhibited on tooth surfaces in contact with a restoration that releases fluoride. It is well documented that fluoride has anticariogenic properties, and the formation of secondary caries is inhibited on tooth surfaces in contact with a restoration that releases fluoride.5

Increasing the resistance of enamel to demineralization is accomplished when the enamel absorbs fluoride, and the mineral becomes fluorapatite. The presence of fluoride reduces the solubility of the apatite and makes it more resistant to demineralization. An additional benefit of fluoride is that it reduces the surface energy of enamel and impedes the attachment of plaque to the tooth surface. Fluoride also inhibits bacterial metabolism as a result of the formation of hydrogen fluoride (HF). Fluoride accumulates in the dental plaque in the form of HF. As it enters the more alkaline intracellular fluid it disassociates into H+ and F- ions. The ionic fluoride induces enzyme inhibition, leading to a slower rate of acid production. Fluoride interferes with bacterial metabolism and decreases the adherence of bacteria to hydroxyapatite.5,19

Fluoride in a restorative material does not last indefinitely, but it can be replaced via toothpaste, topical gels, and mouthrinses, with gel being the most effective means of delivery.20,21 There is no consensus regarding the ideal concentration of fluoride that is released. Further, it is not known how much fluoride is needed to inhibit caries formation.

Some dental materials contain and release fluoride. Glass ionomers can contain fluoride concentrations of approximately 5 ppm.5 It is well documented that fluoride has anticariogenic properties, and the formation of secondary caries is inhibited on tooth surfaces in contact with a restoration that releases fluoride.5

The categories of liners, bases, and cements include varnish, calcium hydroxide, zinc oxide eugenol, non-eugenol zinc oxide, zinc phosphate, zinc polycarboxylate, glass ionomer, and resin. Parts 2 and 3 of this series will review each category and its use as a liner, base, and/or cement. Examples and types of delivery systems will be discussed.

### REFERENCES

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**POST EXAMINATION QUESTIONS**

3. The presence of bacteria on the cavity wall is the main factor influencing pulpal reaction. Sealing the dentin can eliminate postoperative sensitivity.
   a. Both statements are true.
   b. The first statement is true; the second statement is false.
   c. The first statement is false; the second statement is true.
   d. Both statements are false.

4. Proper restorative technique includes ____.
   a. isolation with rubber dam
   b. smooth margins
   c. use of cavity cleansers
   d. all of the above

5. Cohesion is defined as the force of attraction between molecules or atoms of the same kind. Adhesion is the force of attraction between the molecules (atoms) on 2 different surfaces.
   a. Both statements are true.
   b. The first statement is true; the second statement is false.
   c. The first statement is false; the second statement is true.
   d. Both statements are false.

6. To increase the chance of bonding success, ____.
   a. all tooth surfaces should be clean
   b. adhesive should be well-cured
   c. there should be intimate adaptation between all surfaces
   d. all of the above

7. Fluoride reduces the surface energy of enamel. Fluoride increases the solubility of apatite.
   a. Both statements are true.
   b. The first statement is true; the second statement is false.
   c. The first statement is false; the second statement is true.
   d. Both statements are false.

8. The most effective means of replenishing fluoride is via ____.
   a. toothpaste
   b. mouthrinse
   c. tablets
   d. topical gels
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