Liners, Bases, and Cements
An In-Depth Review, Part 2

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LEARNING OBJECTIVES:
After reading this article, the individual will learn:
• the materials that can be used as liners, bases, and cements,
• physical properties and clinical application of liners, bases, and cements.

ABOUT THE AUTHORS
Dr. Weiner received his DMD degree from Tufts University in 1986. He is a Fellow of the Academy of General Dentistry, the American College of Dentists, and the Pierre Fauchard Academy. As an author and lecturer his topic of interest is liners, bases, and cements. He maintains a private practice in Family and Cosmetic Dentistry in Millis, Mass. He can be reached at randy@weinerdmd.com.
Disclosure: In the past, Dr. Weiner has received honoraria for papers written on behalf of GC America and Heraeus Kulzer.

INTRODUCTION
Part 1 of this series discussed the physical properties and clinical indications of dental materials used as liners, bases, and cements. This article will discuss the different types of materials that can be used as liners, bases, and/or cements.

VARNISH
Although many clinicians do not categorize varnish as a liner, a varnish is, by definition, a liner.¹ Varnishes seal dentinal tubules, therefore they are not used prior to the placement of a composite resin restoration. Rather, they are used prior to the placement of an amalgam restoration. A varnish is a solution of one or more resins derived from natural gums, synthetic resins, or rosin; the solvent is acetone, chloroform, or ether.² After placement of the varnish the solvent evaporates, leaving the solute to seal the tubules.
A cavity varnish is used to provide a barrier against irritants (from cements and other restorative materials) and to reduce the penetration of oral fluids into the underlying dentin at the tooth-restoration interface.³ When used under an amalgam restoration, a varnish serves additional purposes. First, after an amalgam is placed it shrinks as it hardens. Eventually the amalgam will undergo corrosion, and these corrosion byproducts will seal the space that develops between the tooth and the restoration. However, until this happens the dentin needs to be sealed to protect the tooth from microleakage. A varnish will accomplish this. In addition, a varnish serves to protect the tooth from the migration of amalgam components (metallic ions) into the tooth structure. These ions are responsible for the darkened tooth color associated with an amalgam restoration.³
Even when multiple layers of varnish are placed, openings may develop that can allow bacteria to penetrate deeper into the dentin. Therefore, varnishes are not as effective as certain other liners.⁴ Never-the less, it has been shown that varnishes are as effective as adhesive liners, at least in the short term.⁵ Further, varnishes do not possess any mechanical strength due to their minimal film thickness, which also makes them inappropriate for thermal insulation or for use as a base or cement.
Because varnishes evaporate, the clinician should remember to keep the bottle closed when not in use to reduce the amount of solvent that evaporates. If the liquid becomes too thick to be used clinically, manufacturers provide a thinner that can be added.
Dentists must be careful to use the correct varnish for a given clinical application, as sometimes the product name can be misleading. Some products are meant to be used as a dentin tubule sealer (eg, Copalite [Cooley & Cooley], Copaliner [Bosworth]), while others are meant to seal glass ionomer restorations (eg, Fuji Varnish [GC America]).
In a recent survey of North American dental schools regarding instruction in the use of liners, bases, and cements, only 20% of respondents reported that they teach the placement of a varnish in a shallow tooth preparation, and only 3% teach varnish placement in a deep cavity preparation.⁶
CALCIUM HYDROXIDE

Calcium hydroxide (CaOH) is considered a liner because it is suspended in a solvent with a thickening agent. As with a varnish, the solvent evaporates, leaving behind (as a liner) a layer of CaOH. However, Craig and Powers consider CaOH a low-strength base.3

Calcium hydroxide has 2 components: a base and a catalyst. The base portion contains calcium tungstate, tribasic calcium phosphate, and zinc oxide in glycol salicylate. The catalyst is composed of calcium hydroxide, zinc oxide, and zinc stearate in ethylene toluene sulfonamide. The calcium tungstate, or in some cases barium sulfate, are fillers used to provide radiopacity.3

CaOH can have a pH as high as 12. The high pH can lead to mild to moderate cytotoxic effects for cells in the pulp as well as bacteria in dentin and spaces between the tooth and restoration. Thus, this material can be antibacterial. In addition, due to its alkaline property it counteracts the acidic byproducts of bacteria. This property results from the catalyst component.7 According to Ferracane, CaOH continues to have a high pH even after setting, because the material leaches out hydroxyl ions after coming in contact with moisture (dentinal fluid).8

The alkaline nature of CaOH causes it to be an irritant to the pulp. Initially, the pulp undergoes necrosis to a depth of 1 mm or more. After 5 to 8 weeks only a slight inflammatory response remains. At the same time dentin bridge formation (reparative dentin) begins.3 This dentin bridge formation takes place because CaOH can extract growth factors from the dentin matrix.9 Formulations that contain resin may allow this process to occur more quickly.9

Light-cured formulations of CaOH are available that have urethane dimethacrylate resin added to the catalyst. These products are not harmful to the pulp, and do not exhibit any of the antibacterial properties of the self-cured formulations.3 These products have faster setting times and lower solubility than self-cured varieties.

Although CaOH has an initial low compressive strength, this strength may continue to rise over the first 24 hours (depending on the brand). Tensile strength and modulus of elasticity are also low. It is interesting to note that even though Craig and Powers3 refer to CaOH as a base, they suggest that it not be applied in thicknesses greater than 0.5 mm, actually making this material a liner.

The advantages of CaOH include easy manipulation, rapid hardening in thin layers, a relatively good seal, and some beneficial effects on carious dentin and the exposed pulp. Its disadvantages include low strength, plastic deformation, and high solubility in water (self-cured formulations).

Although not usually considered a cement, CaOH is an acceptable temporary or short-term cement. This material is strong, is easily cleansed from resin temporary crowns, and is easily removed from the inside of temporary crowns. The light-cured varieties are not to be used as a cement, since a curing light will not reach under the restoration. Only 5% of North American schools teach the use of CaOH as a temporary cement.6

CaOH will dissolve when in contact with saliva, meaning that closed margins are essential when CaOH is used as a temporary cement. Calcium hydroxide does not bond to dentin, allowing easy removal from the preparation.10 Examples of calcium hydroxide products are Dycal (DENTSPLY Caulk) and Life (Kerr), all of which are paste-paste products.

ZINC OXIDE EUGENOL

Zinc oxide eugenol (ZOE) material has been available since the late 1800s and is considered to be the least irritating of all dental materials. It has a pH of approximately 7 and is reported to have a sedative effect on the pulp.3 However, in high concentrations eugenol can be toxic. Therefore, it should not be placed in direct contact with the pulp.

ZOE is governed by ADA Specification #30, in which there are 4 types or categories. Type 1 is for temporary cements, Type 2 for final cements, Type 3 for temporary fillings and bases, and Type 4 for interim restorations (Type 4 will not be discussed in this article since the clinical application is not for a liner, base, or cement).

The main components are zinc oxide and eugenol. ZOE products are available in paste-paste or powder-liquid varieties. The powder contains zinc oxide (70% by weight) with rosin added to reduce the brittleness of the mixture. The liquid portion contains eugenol, which is derived from oil of cloves, one of the essential oils. Eugenol is
bactericidal, but becomes more effective when combined with zinc oxide, which alone has no inhibitory effect.\textsuperscript{11}

Hume\textsuperscript{12} demonstrated that dentin reduced the rate of release of eugenol from ZOE compared to the release of eugenol into saline. Eugenol is released from ZOE by hydrolysis. The dentinal wetness allows just enough eugenol release to establish a concentration gradient through the dentin to kill bacteria in the adjacent dentin, but not enough to kill pulp cells. In a saturated environment (unlimited wetness), much more eugenol is released, which when placed in direct contact with the pulp can cause pulpal death. Hume also notes that the dentin effectively protects the pulp from chemical irritation, but that this protection decreases as the remaining dentin thickness decreases.

ZOE provides an excellent seal at the restoration-tooth interface, despite the fact that it does not adhere to tooth structure.\textsuperscript{8} In fact, the lower the powder/liquid ratio (P/L), the better the seal.\textsuperscript{13} This seal prohibits diet-derived substrate from reaching microorganisms beneath the restoration, thus reducing acid production and the chance of developing caries. Further, ZOE inhibits bacterial cell metabolism.\textsuperscript{13} These facts explain the low incidence of postoperative sensitivity.

The setting of ZOE is due to hydrolysis of the zinc oxide followed by a reaction between the resulting zinc hydroxide and the eugenol. The reaction needs water to begin (water is also a product of the reaction), and explains why the reaction is faster in the presence of moisture.\textsuperscript{2}

ZOE can be prepared as either a thick or thin mixture. This makes it suitable for more than one clinical situation. Ideally, ZOE is slowly wetted by the liquid, therefore a prolonged and vigorous spatulation is required. These products can be mixed on a cool glass slab (below the dew point) to slow the setting reaction. If the mixing surface is too warm, moisture may become incorporated in the mix, thus speeding the setting reaction. This material is not exothermic upon mixing, and Craig and Powers note that a cold glass slab is not necessary.\textsuperscript{3}

Zinc oxide eugenol is not usually marketed or used as a cavity liner. Some formulations may contain polymethylmethacrylate (PMMA, up to 20\%) in the powder to strengthen the product, which makes it more suitable as a cavity base.\textsuperscript{3} The compressive strength of zinc oxide eugenol reaches its maximum in about 15 minutes. Craig and Powers\textsuperscript{3} consider this material a low-strength base. ZOE has thermal insulating properties that are approximately the same as dentin.

As the P/L increases, the mix becomes drier. This in turn results in less free eugenol (as it is tied up in the mix) to act as an irritant to the pulp. This mix is also less tacky, which makes it easier to work with.

ZOE cements are formulated for two purposes: as a temporary cement and as a final cement. With respect to temporary cements, these products (unmodified formulations) must have a low strength so that the temporary restoration can be removed without damaging the tooth. These materials can, for a short period, provide a good marginal seal, thus reducing microleakage.

It has been reported that some people experience post-preparation pain following certain restorative procedures. When a 4\% potassium nitrate-ZOE temporary cement is used during the provisional period, the incidence and severity of pain is significantly reduced.\textsuperscript{15}

The ADA specification requires that the film thickness for ZOE temporary cements be no greater than 40 \(\mu\)m, versus 25 \(\mu\)m for final cements.\textsuperscript{3} With respect to using ZOE as a final cement, clinicians will find that these materials have both improved strength and abrasion resistance. This is achieved by having either methylmethacrylate or alumina added to the powder, and ethoxybenzoic acid added to the liquid. For Type 2 materials, the smaller the particle size, the stronger the final mixture. Further, these materials can be more difficult to manipulate in the mouth. Their film thickness is high, and removal of the excess is difficult.\textsuperscript{3}

Anusavice\textsuperscript{2} recommends not using ZOE to temporarily cement final restorations because this may result in difficulty removing the restoration, which could damage the integrity of both the restoration and the tooth. There is only one ZOE-based final cement available (Fynal [DENTSPLY Caulk]), indicating that these materials are not very popular for that purpose. This could be due to the fact that ZOE cement disintegrates rapidly when exposed to the oral cavity.\textsuperscript{10} Further, a review of the literature could not identify any recent studies
that include evaluation of a ZOE-based final cement.

Examples of zinc oxide-based materials are ZOE Plus (Temrex), IRM (DENTSPLY Caulk), TempBond (Kerr), and TempoSIL (Coltène/Whaledent). Configurations of ZOE products include paste-paste, powder-liquid, and encapsulated.

**NONEUGENOL ZINC OXIDE**

Zinc oxide eugenol-type materials that have had the eugenol portion replaced with carboxylic acid are classified as noneugenol zinc oxide (NZOE). These products are only available for use as a temporary luting agent (not a liner or base), and are promoted for use when a resin cement is to be used for the final restoration. Additionally, a NZOE product can be used for patients who are sensitive to eugenol. Christensen writes that manufacturers’ recommendations to use these products are not based on a documented need. Manufacturers are currently marketing noneugenol products for use as temporary cements that contain ingredients such as chlorhexidine (for its antibacterial effect) and potassium nitrate (to reduce postoperative sensitivity).

Clinicians who use preformed metal crowns as temporary crown restorations may find that NZOE products do not adhere as well as do the eugenol-containing cements. In addition, NZOE products have a slower setting time than ZOE products.

Craig and Powers state that NZOE products do not soften temporary acrylic restorations. This implies that ZOE products do soften acrylic, but this is not directly stated in their text. Note that the subject of ZOE-resin incompatibility will be covered in the final part of this series. Examples of NZOE products include PreVISION (Heraeus Kulzer), TempBond NE (Kerr), and Temp Advantage (GC America). Clinicians can choose from 2 delivery systems: paste-paste and auto-mix syringe.

**ZINC PHOSPHATE**

Zinc phosphate (ZOP) has been in clinical use longer than any other type of cement, and in many studies it is used as the control. The powder is composed of zinc oxide (90%) and magnesium oxide (10%). Certain other chemicals may be added, eg tannin fluoride may be added as a source of fluoride (Shofu products). The liquid contains phosphoric acid, water, and aluminum phosphate (which acts as buffering agent). The water influences the rate of the acid-base reaction. Loss of water from the reaction can lengthen the setting times; adding water shortens setting times. A change in water content can reduce both compressive and tensile strength.

ADA Specification No. 96 (water-based cements), which covers ZOP, requires setting times to be between 2 and 8 minutes. There are instances when a clinician needs to extend the working time. This can be accomplished 4 ways: 1) reduce the P/L, which will lower the pH; 2) add the powder to the liquid a little at a time; 3) delay mixing the last amount of powder, which will destroy the matrix, requiring it to reform when the last powder is added; or 4) mix on a cold glass slab, thus cooling the exothermic reaction (caused by the surface of the alkaline powder dissolving in the acid liquid). This slows the...

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**Figure 1.** Materials that can be used as a cavity liner.
A chemical reaction that occurs between the powder and liquid and is the most effective way to extend the working time. This also allows more powder to be added, which will improve the physical properties. When mixing on a cool slab, one must be certain that the slab is dry, otherwise moisture will dilute the liquid and shorten the set time.

The pH of the mix is approximately 2 when the mixing is complete, but at 24 hrs it is 5. The liquid should be protected at all times, since if the water evaporates the liquid will be more acidic, making the mix thicker. This will result in an increase in the film thickness, making seating of a casting more difficult. To account for this evaporation clinicians should be aware that according to Specification #96 there will be 20% more liquid in the package than what is needed for the powder. This accounts for any evaporation. Using a product with the liquid in a “squeeze” bottle rather than one that requires the use of an eye dropper reduces the tendency for gain or loss of water from the liquid.

The advantages of ZOP are as follows: it is easily mixed, is relatively strong, and has a long history of clinical success. ZOP’s disadvantages are questionable pulpal irritation, lack of antibacterial action (except copper-based versions), brittleness, lack of adhesion, and solubility in oral fluids.

Approximately 100 years ago, copper-based ZOP products were introduced and were believed to be antibacterial. Cooley & Cooley has reintroduced copper-based ZOP and cites unpublished studies from Montana State University’s Center for Biofilm Engineering and Loma Linda University to confirm the antibacterial properties. Although ZOP is not usually considered a liner, Cooley & Cooley does suggest mixing its copper-based Doc’s Best ZOP cement with varnish to achieve a thin mix for use as a liner.

When mixed to a thick, dry putty consistency, ZOP (both conventional and copper-based) can be used as a strong, hard base. With its relatively short setting time, a final restoration can be placed at the same visit. The ZOP will provide a thermal and chemical barrier. In addition, this consistency has less free liquid available to act as an irritant.

The maximum film thickness for ZOP is 25 µm when used as a luting agent (Type 1). Because the viscosity of the mix increases rapidly, seating of a casting must take place immediately after mixing, otherwise it may be difficult to seat the restoration. Also, the smaller the particle size, the faster the set.

Initially, ZOP will undergo a slight expansion (due to water absorption), then the material will shrink after hardening. It has been suggested that after removal of the excess cement, a layer of varnish be applied to the margin if the margin is supragingival. This will allow the cement to mature and be more resistant to dissolution in the mouth.

Zinc phosphate does not adhere to tooth structure via chemical interaction, but instead by physical interlocking at the interface. When used as a cementing agent, the length, taper, and surface area of the preparation are crucial to its success. The ADA Specification requires that, when ZOP is used as a cement, the particle size must be less than 25 µm to allow the material to flow properly and to fill the irregularities on the surface of the preparation. It has been shown that ZOP has self-etching properties that are effective in removing the smear layer and promoting close contact.

Figure 2. Materials that can be used as a base.
adaptation to the dentin surface.\textsuperscript{18}

The liquid component of ZOP is very acidic, and it was once believed to be the cause of the postoperative sensitivity associated with its use. It has since been shown that this is not true.\textsuperscript{19} Despite this, as a preventive measure many clinicians place a varnish on the dentin prior to the placement of ZOP.

When ZOP is used as an orthodontic cement gross decalcification of the enamel may be observed. This is due to loss of cement between the band and the tooth, and therefore, this interface becomes a favorable environment for bacteria.\textsuperscript{3} Examples of ZOP materials are Fleck’s (Mizzy) and Doc’s Best Copper Cement (Cooley & Cooley). Zinc phosphate is only available in a powder-liquid system.

**ZINC POLYCARBOXYLATE**

Zinc polycarboxylate (ZPC) was developed in the 1960s to offer both the strength of ZOP and the biocompatibility of ZOE. It is also referred to as zinc polyacrylate. Addressed under ADA Specification #96, this powder-liquid material actually chemically bonds (ionic) to the tooth. This bond to the tooth is due to the polyacrylic acid (negative charge) reacting with the calcium (positive charge) ions via carboxyl groups on the surface of the enamel and dentin, with the bond to enamel being greater than that to dentin. The liquid component contains a 35\% to 40\% aqueous solution of polyacrylic acid, which is what makes these products different from ZOP. The powder contains zinc oxide with magnesium oxide. As with some zinc phosphate products, some ZPC may have stannous fluoride added. Anusavice writes that the amount of fluoride release is about 15\% to 20\% of that released from glass ionomers.\textsuperscript{2} The fluoride will enter adjacent enamel and will exert some anticariogenic effect.\textsuperscript{10}

The mix appears to be thicker than ZOP (due to the liquid component), and thus is pseudoplastic, meaning the correct consistency is found in a mix that is viscous but will flow back under its own weight when drawn up with a spatula. The working time is half that of ZOP, and the mix is not as stiff as zinc phosphate. The liquid does not need to be refrigerated (as it will form into a gel). If the liquid is refrigerated, clinicians should warm it prior to use. When mixing, clinicians should incorporate the powder into the liquid at once, versus a little at a time, as with ZOP. Zinc polycarboxylate is considered by some to be the most biocompatible cement even though the liquid has a 1.7 pH. This pH is rapidly neutralized when mixed with powder. ZOP is less acidic than ZPC, but the pH of ZPC rises faster than ZOP. Histologic reactions of pulpal tissue to ZPC appear similar to ZOE, and ZPC does induce reparative dentin formation.\textsuperscript{3}

This material is biocompatible because the large polyacrylic molecules cannot diffuse into dentin, there is a rapid rise in pH to neutrality, and lastly, there is minimal dentinal fluid movement in response to the material.\textsuperscript{10} The biocompatibility of ZPC is similar to that of ZOE.

As with ZOP, the liquid component of ZPC quickly loses water due to evaporation, which increases viscosity. With this
material the powder is incorporated into the liquid in total. The mixture must be used prior to loss of the glossy appearance. The glossy appearance means that there are enough free carboxylic acid groups to bond to tooth structure. As with ZOP, due to its acidity ZPC is self-etching, which helps remove the smear layer and allows for close adaptation to the tooth. When mixed with potassium nitrate it serves as an effective liner, base, and cement, as it has been shown to preserve pulp vitality when less than 1 mm of dentin remains. However, clinicians may find it difficult to use ZPC as a liner due to its viscosity. As with ZOP, a thicker, drier mix should be made if the ZPC material is to be used as a base. The final restoration can then be immediately placed.

Clinicians have a tendency to spatulate zinc polycarboxylate so it is as thin and fluid (low powder/liquid ratio) as is a mix of ZOP. This will result in a mixture that has poor physical properties. With ZPC, the failure occurs at the cement-metal interface, compared to ZOP which fails at the cement-tooth interface. Because of the plastic deformation potential it can be difficult to remove excess ZPC. Removal of cement should only be attempted after complete setting of the material. If done while still in the rubbery stage, there is risk of a tear from beneath the margins, leaving a void that will be difficult to cleanse and could lead to recurrent caries.

A study comparing ZOP and ZPC used with inlays in deep preparations concluded that neither material produced any notable irritating effect on the pulp. The only irritation was observed in 2 ZOP inlays, and that was attributed to bacteria and other debris remaining in the cavity preparation. In spite of this finding, none of the dental schools in that 2005 survey reported using ZPC as a liner, base, or cement.

ZPC material has numerous advantages, which include biocompatibility, adhesion to the tooth, easy manipulation, and strength. Its disadvantages include the need for accurate proportioning, lower strength and greater viscosity than ZOP, shorter working time, and the need for a clean tooth surface for optimal adhesion. Zinc polycarboxylate products include HY-Bond Polycarboxylate Cement (Shofu, both as a temporary and final/permanent formulation), Durelon (3M ESPE), and LivCarbo (GC America). Clinicians will find this material available in powder/liquid and encapsulated varieties.

**CONCLUSION**

This article has discussed many of the available materials that can be used as liners, bases, and/or cements (Figures 1 to 3). The next article in this series will discuss glass ion-omers and resins.
REFERENCES


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POST EXAMINATION QUESTIONS

1. Use of a varnish will ____.
   a. provide a barrier against irritants
   b. reduce the penetration of oral fluids into the dentin
   c. protect the tooth from metallic ion migration
   d. All of the above.

2. Calcium hydroxide has a low pH. Because of this acidic property, CaOH is antibacterial.
   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.

3. The pH of ZOE is neutral. Its anti-bacterial effect is due to the eugenol component.
   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. ZOE provides an excellent seal at the margin. NZOE materials are not intended to be used as a liner or a base.
   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.

5. NZOE products are ZOE materials with that have had the eugenol replaced with phosphoric acid. NZOE products are only used as temporary cements.
   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. ZOP is available in both paste-paste and powder-liquid formulations. ZOP has a long history of clinical success.
   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.

7. ZOP adheres to the tooth via a physical interlocking mechanism. Copper based ZOP has antibacterial properties.
   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. With respect to ZPC, the pH of the liquid is quickly neutralized when mixed with the powder. When ZPC is used as a cement the excess should only be removed after it is completely set.
   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.
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