Current Status of Glass Ionomers

by Dr. Karl F. Leinfelder

Abstract

Continuous research efforts around the world have led to a great number of applications for the glass ionomer. Some of the efforts have resulted in the substitution of this agent for composite resins in primary teeth. When used in conjunction with a surface-penetrating agent, the wear resistance of the ionomer can be improved appreciably. The glass ionomers provide excellent resistance to micro-leakage but they also release effective levels of fluoride ions. At least one clinical study has shown that glass ionomers are clinically effective in reducing the amount of secondary caries, particularly as compared to amalgam.

Glass ionomers can be successfully used as a liner under various types of restorative systems. When used under composite resins they offer great resistance to post-operative sensitivity as well as a fluoride-releasing source. The resistance to post-operative sensitivity can be related to its matched coefficient of thermal expansion with tooth structure. Their effectiveness has led to the substitution of this agent for a flowable composite resin by a large number of clinicians. It should be mentioned that the glass ionomer should be considered for the construction of the floor of the proximal box when the preparation is extended gingival enough to reduce substantially (or eliminate) the enamel wall.

Educational Objectives

At the end of this course the participant will be able to:

1. Identify the advantages of glass ionomers as a restorative agent.
2. Make recommendations for the restoration of posterior preparations in primary teeth in cases of moderate to high incidences of caries.
3. Identify the types of sandwich techniques and the objectives of each.
4. Define methods for restoring abfracted lesions.
5. Discuss the etiology of post-operative sensitivity.

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Glass ionomer cement (GIC) was developed as a luting agent by professors Wilson and Kent nearly 40 years ago.[1] A patent for this innovative concept was subsequently applied for in 1969. Its interesting history is shared with a couple of other restorative systems including polycarboxylate cement (PCA) and silicate cement. While the PCA was the first restorative system to bond to tooth structures, silicate cement effectively released fluoride ions to actively resist or prevent caries. The glass ionomer actually possesses both these potentials.

The powder component of the original glass ionomer was similar to the powder of silicate cement.[2] In general, it is a finely ground ceramic glass, soluble in acids. The primary component of the GIC was SiO_2 and Al_2O_3. It contained also lesser amounts of NaF, CaF_2 and $AlPO_4$. The liquid component on the other hand consisted of polyacrylic acid and tartaric acid (approximate ratio of 10:1). The reaction between the liquid and the powder is essentially an acid-base reaction. The reaction is rather complex.

Over the years the formulation has changed. Today, glass ionomers are considerably easier to manipulate. One of the great improvements has come about with the addition of a resin component. Commonly referred to as RMGI or resin modified glass ionomer, they are widely used for any application from liners to bases to luting agents. By incorporating the resin, many of the physical and mechanical properties have been improved dramatically. Most notable amongst the changes was the ability to control the setting time. One of the more interesting systems was Vitremer (3M ESPE). Identified as a photocured glass ionomer cement, this agent consists of a difunctional molecule. One end of the polymeric chain exhibits a chemical affinity for glass and the other end for tooth structure. Interestingly, this system will cure with light radiation or in a self-cure mode.

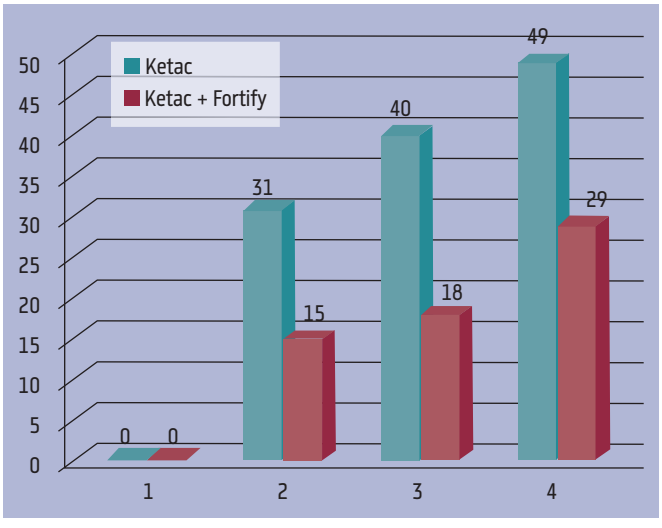

Fig. 1: In vitro wear rates of KetacFil and KetacFil + Fortify.

Clinical Considerations

The use of aesthetic restorative agents has become quite acceptable in pediatric restorative procedures. In this regard, composite more closely resembles the physical nature of natural teeth. However, composites might not be the best choice when dealing with posterior teeth. It is now recognized that caries, when present, progresses appreciably faster under composite restorations than it does with amalgam. The exact reason(s) incidentally has not been published. It is quite possible that the metal ions associated with amalgam (silver, copper, tin, zinc or even mercury) might serve as anticariogenic agents. In the case of composite resins there is nothing in the composition to generate such an action.

It is for this reason that glass ionomers have been recommended by some as a possible aesthetic material for the restoration of Class I and II cavity preparations in primary teeth. Unfortunately the glass ionomer might not be sufficiently wear-resistant over long periods of time (i.e., six to eight years). It has been suggested that perhaps a surface penetrating agent such as Fortify (Bisco) might be useful in enforcing the occlsual surface, thereby rendering it more resistant to clinical wear. Traditionally, the only way to determine efficacy would be clinical studies.

Using an in vitro device developed at the University of Alabama, it is now possible to determine the long-term wear rate and marginal integrity of aesthetic restorative materials.[3] Specifically, the instrument will generate the actual wear resistance of direct filled aesthetic restorative materials that normally occurs in three years of clinical service in three days. Examples of restorative agents that can be tested for long-term clinical performance include composite resins (direct and indirect), compomers and glass ionomers. Resistance to marginal degradation or "ditching," which is common to microfills when used on occlsual surfaces, can also be predicted. A comparison of 10 different posterior composite resins for wear over a three-year period showed remarkable correlations to the in-vitro data. Values measured for each year agreed to within three microns for each material tested. Such a device has helped various manufacturers to test their product using the in vitro device before actually marketing their system.

In a study conducted at the University of Alabama, teeth were restored with a glass ionomer (KetacFil) and then were surfaced with Fortify. Using the wear-determining device developed at UAB, the wear rates of the glass ionomer were measured and compared to those that received the Fortify treatment (Fig. 1).

1. *Wilson AD and Kent BE: A new translucent cement for dentistry; the glass ionomer cement. Br Dent J 132(2): 133-135, 1972.*
2. *Crisp S and Wilson AD: Reactions in glass ionomer cements V. Effect of incorporating tartaric acid in the cement liquid. J Dent Res. 55:1023-1031, 1976.*
3. *Leinfelder, K.F., Beaudreau, R.W. and Mazer, R.B. An in vitro device for predicting clinical wear. Quint. Inter. 20:755-761, 1989.*

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The application of the surface-penetrating sealant (Fortify) enhanced the wear resistance by approximately 40 percent. The positive effect of the Fortify can be seen throughout the entire testing period. The total time of testing was equivalent to three years of clinical use. It is probable that by the end of three years that the surfaces of the glass ionomer restorations need to be recharged with the sealant since the depth to which the sealant had penetrated originally might be worn away. At least one clinical study has demonstrated that Fortify appreciably enhanced wear resistance of composite resins as well as marginal adaptation (marginal integrity).[4,5]

The procedure for using the surface penetrating sealant is quite simple. Upon completion of the cavity preparation and surfacing with an appropriate conditioner, a glass ionomer restorative material (Fuji IX, Fuji II LC, KetacFil) is used to restore the tooth. Upon completion of cure (light) the occlsual surface is acid etched for approximately 10 seconds. After washing and drying, Fortify surface-penetrating agent is applied with a small brush or cotton pledget, lightly air dispersed and then light-cured. Since the film thickness of this agent is only 5 microns, it doesn't interfere with the occlusion. Due to the very low viscosity of the surface penetrating agent, it rapidly penetrates the microporous surface, thereby enhancing its integrity. Interestingly, there are two variations of the Fortify; Fortify and Fortify Plus. The latter contains colloidal silica and as a result will generate a relatively smoother surface.

Further Uses

Glass ionomers like composite resins have been available to the dental profession for nearly four decades. Both of them have experienced major advances not only in clinical characteristics but applications as well. Glass ionomers, particularly those that have been modified with a polymer component, have been recommended for the following uses:

1. Liners/bases under various restorative materials
2. Cavity preparations in primary teeth (Classes I and II)
3. Cervical restorations (abfractions and caries)
4. Defects and undercuts
5. Caries control (temporary restorations)
6. Core buildups
7. Luting agents for crowns, inlays/onlays

Many clinicians routinely use a glass ionomer liner in conjunction with teeth to be restored with either composite resin or amalgam. Interestingly, the incidence of post-operative sensitivity is dramatically reduced when the preparation is lined with glass ionomer. While the thickness of the liner is not critical, it is recommended that it should be at least one millimeter in thickness. It is important to cover the entire pulpal floor, pulpal axial line angle and the dentin located on the gingival floor. The glass ionomer can serve as a substitute for the flowable composite resin.

The avoidance of post-operative sensitivity probably can be attributed to the fact that glass ionomers inhibit micro-leakage and thus post-operative sensitivity. The reason can be related to the fact that the coefficient of thermal expansion of the glass ionomer is very close to that of tooth structure.[6] Consequently, any increase or decrease in temperatures will cause the two substances to expand and contract similarly. This then avoids the effect of a pumping action at the interface, which will cause negative pressure on the surface of the odontoblastic processes and then pain.

The concept of pain or post-operative sensitivity (POS) has been widely investigated by Brännstrom. In essence he has demonstrated that anything that causes a movement of the odontoblastic fluids over the body of the odontoblastic process will create a negative pressure.[7] This, in turn, will create a painful response. Positive pressures, by the way, do not.

A diagrammatic illustration of the factors that generate sensitivity are illustrated in Figure 2. There are numerous clinical conditions that contribute to fluid flow over the surface of the odontoblastic process. The first of these is the application of air onto the surface of the cut dentin. Without an anesthetic, the patient invariably complains of pain or sensitivity. The burst of

Fig. 2: Mechanism of Sensitivity

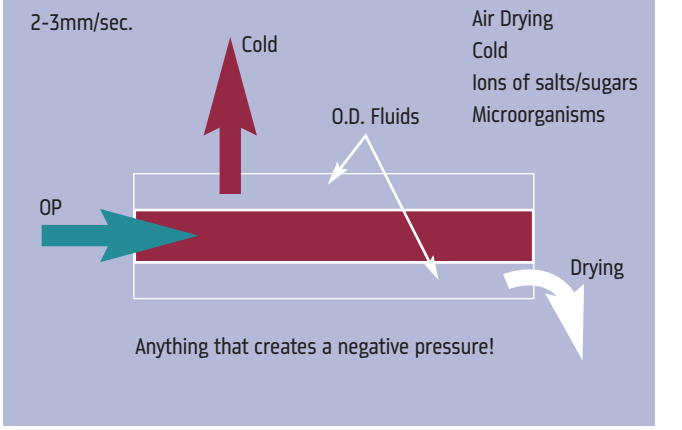

Fig. 2: Diagrammatic illustration of cause of post-operative sensitivity.

4. *Dickinson, G.L., Leinfelder, K.F., Mazer, R.B. and Russell, C.M. Effect of surface penetrating sealant on wear rate of posterior composite resins. JADA 121:2, 251-255, 1990.*
5. *Dickinson, G.D. and Leinfelder, K.F.: Assessing long term effect of surface penetrating sealants: JADA 124:68-172, 1993*
6. *Bullard, H., Leinfelder, K.F. and Russell, C.W.: Effect of coefficient of thermal expansion on microleakage. JADA 116:871-874, 1988.*
7. *Brännstrom, M, The effect of dentin desiccation and aspirated odontoblasts on the pulp. J Prosthet Dent 20(2): 165-171, 1968*

air creates an evaporation of the fluids, thereby creating a temporary negative pressure. The sensitivity will continue until fluids from the inner region of the process migrate over the affected area. This normally takes several seconds.

According to Brännstrom, cold temperatures applied to the freshly cut dentin and cervical lesions cause a contraction of the fluids surrounding the odontoblastic process. This in turn creases a negative pressure and again a painful response. The pain will continue until the temperature of the fluids increases back to normal physiologic conditions. Ions of sugar and salts will contribute to pressure changes and painful response. The same can also be said of microbial activity. The glass ionomer, when placed on the freshly cut dentinal surface, effectively acts as a seal. Not only does it bond to the surface of the tooth but it also closes off the dentinal tubules.

Incidentally, when the proximal box (Class II preparation) is sufficiently deep so that little or no enamel exists, it is recommended that the box portion consist of glass ionomer. Procedurally, the glass ionomer should form the box portion of the preparation to a thickness of about 2mm. It is well-recognized that the proximal region of the Class II is the Achilles' Heel of this type of restoration. Again, lack of micro-leakage and fluoride release provide insurance against clinical failure.

Identified as the sandwich technique, there are two types. These include the open and closed technique. If any of the surfaces of the glass ionomer liner are exposed to the oral cavity it is referred to as open. If none of the glass ionomer is exposed (completely imbedded) it is identified as a closed sandwich technique. A diagrammatic illustration of the two types is presented in Figure 3.

Fig. 3: Sandwich Techniques

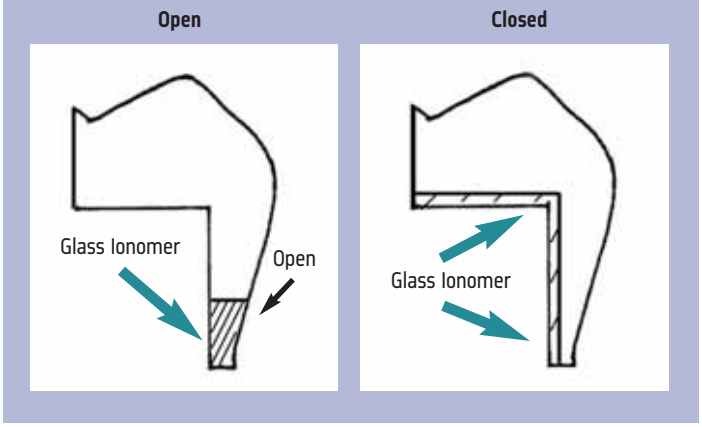

Fig. 3: Diagrammatic illustration of open and closed sandwich techniques.

"Today glass ionomers are considerably easier to manipulate. One of the great improvements has come about with the addition of a resin component."

Abfractions/Caries

Defects occurring in the cervical regions can be treated in a number of ways. The manner selected, however, can depend upon the general age of the patient. In general, the technique is somewhat similar for both the abfracted lesions and those involving carries.

Abfracted Lesions

In recent years there has been considerable information published and discussed related to "natural" occurring defects in the cervical region (both facial and lingual). Although not unanimously agreed upon, it is generally believed that the defects identified as abfractions are due to a deflection of a tooth or teeth beyond its normal physiologic limit. Small cracks begin on the tooth surfaces which then propagate until small pieces break away (abfraction).[8]

Regardless of whether the defect was created by deflection or caries, the principles of restoration are similar. In the case of elderly patients, the occlusion is evaluated for occlusal prematurity, particularly as it relates to the tooth on which the defect occurs. If a prematurity or heavy contact is uncovered, it should be corrected. Next the surface of the defect is slightly roughened with an appropriate instrument.

This is followed by generating a small mechanical undercut on both the occlusal (incisal) and gingival aspect of the defect. Next, acid etch (or etch with bond depending upon which bonding agent is used) followed by bonding. After completion of the hybridizing procedure, it is recommended that a glass ionomer (Fuji IX or Fuji II LC) be used to restore the defect. Glass ionomers are the materials of choice in dealing with geriatric patients. As one ages, the normal physiologic flow of salivary fluids is reduced thereby inhibiting washing of the surface. The glass ionomer is believed to compensate for this aging problem by releasing fluoride into the surface of the defect.

In the case of younger patients, a micro-fill or wear-resistant flowable resin should be considered as the restorative agent. While some of the current day glass ionomers are

8. *Lee WG and Eakle WS: Possible role of tensile stress in the etiology of cervical erosions of teeth. J Prosthet Dent 52(7):341-380, 1989.*

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quite aesthetic, they might not exhibit the same surface characteristics and translucency as the microfills. Other than the restorative agent, the technique used for either young or older patients is essentially the same.

Caries Resistance

Silicate cements have long been credited for eliminating or reducing the potential for generating primary and secondary caries. The many years of history associated with their use has convinced the profession that silicate cement is most effective in this regard.

Given the same time frame for glass ionomer it is more than likely that the same relationship will be established. Interestingly, however, a study conducted by Haberman and Burgess at LSU School of Dentistry has demonstrated the caries retardation effect associated with glass ionomers (Fig. 4). While full proof of caries prevention would take a large number of patients and years of investigation, this study has made an important inroad.

In that study the authors selected a group of patients who exhibited poor caries resistance. In those patients they inserted amalgam and two types of glass ionomer. At the end of two years, the amount of secondary caries associated with the amalgam restorations was significantly greater than in the case of the restorations of glass ionomer.

Treatment of Cavity Preparations Prior to Restoration

The literature is filled with recommendations for treating the preparation prior to insertion of the restorative material.

Fig. 4: Percent of Caries Free

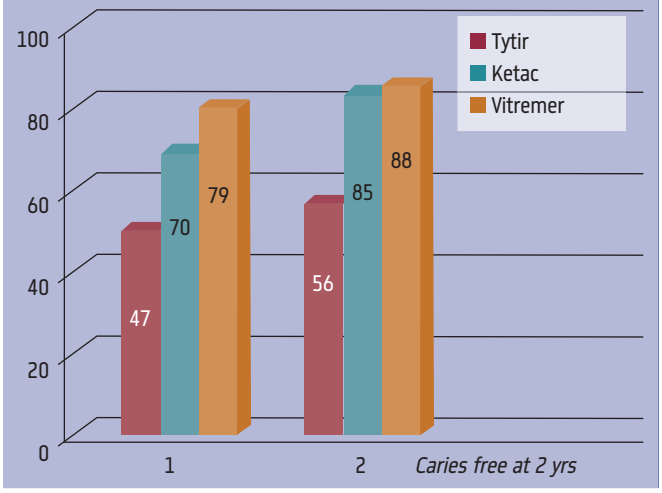
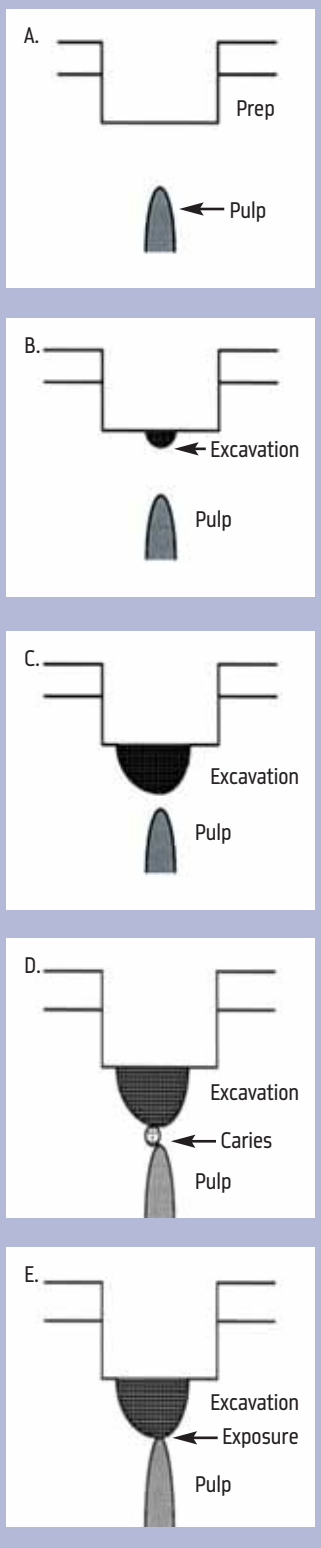


Fig. 4: Percent of recurrent caries associated with restorations of amalgam and glass ionomer.

Fig. 5: Techniques for Treating Cavities



Standard Preparation:
Hybridize

Extended Preparation:
Hybridize

Deep Excavation:
(possible micro exposure)
$Ca(OH)_2$
Glass Ionomer
Hybridize

Residual Caries:
(<1mm in diameter)
$Ca(OH)_2$
Glass Ionomer
Hybridize

Pupal Exposure:
(slight)
$Ca(OH)_2$
Glass Ionomer
Hybridize

Fig. 5: Diagrammatic illustration of techniques used for treating cavity preparations.

"In the case of a standard cavity preparation, it is recommended that the preparation be hybridized (amalgam or composite). Such a treatment not only prevents post-operative sensitivity but also prevents the invasion of micro-organisms into the dentinal tubules. Even in conservative preparations (composites) it is recommended that a glass ionomer liner or flowable composite resin be employed."

While general agreement exists prior to the advent of composite resins, the more current literature is less unanimous in suggesting types of treatment. As a result, there are now clinical questions about the use of glass ionomers, dentin adhesives, liners, bases (i.e., calcium hydroxide) and even acid-etching pulpal exposures.

General recommendations for treatment of the preparation, depending upon the extent of dentin removal, are presented in Figure 5. In the case of a standard cavity preparation, for example, it is recommended that the preparation be hybridized (amalgam or composite). Such a treatment not only prevents post-operative sensitivity but also prevents the invasion of micro-organisms into the dentinal tubules. Even in conservative preparations (composites) it is recommended that a glass ionomer liner or flowable composite resin be employed. No calcium hydroxide (Dycal, Dentsply) is suggested. Should the preparation be extended two to three millimeters beyond the normal outline form, the same treatment is appropriate.

Now if the preparation is extended just short of the pulpal chamber, then a thin layer of calcium hydroxide over the extended portion of the preparation is recommended. Since Dycal ($CaOH)_2$ liberates hydroxyl ions, the resultant increase in pH kills any of the caries-producing micro-organisms that might be present. The surface of the $CaOH_2$ is then covered with a thin layer of glass ionomer. Next the preparation is hybridized and then restored.

If removal of a small amount of residual caries (i.e., 1mm) is left to prevent the possibility of a mechanical exposure, the area is covered by $Ca(OH)_2$. Next the liner of $Ca(OH)_2$ is surfaced with a one to two millimeters of glass ionomer. After hybridizing the restoration is inserted. If, however, a small exposure occurs during a deep excavation, the slight exposure (after cessation of the hemorrhaging) is covered with a millimeter of Dycal. After setting, the surface is then covered with a one to two millimeter layer of glass ionomer. The glass ionomer serves to prevent transmission of condensation forces and thereby distention of the $Ca(OH)_2$ into the exposed surface. Such a condition could cause necrosis of the pulp.

The use of glass ionomer is quite popular on a worldwide basis. For some reason they have been less than totally accepted as a direct and indirect agent in the United States. Fortunately this has changed in recent years due to the excellent clinical results reported by the profession. ■

Author's Bio

Dr. Karl F. Leinfelder earned both his Doctor of Dental Surgery and Master of Science (dental materials) degrees from Marquette University. He joined the faculty of dentistry at the University of North Carolina in 1970. In 1983, he joined the School of Dentistry at the University of Alabama and is the recipient of the Joseph Volker Chair. He also served as Chairman of the Department of Biomaterials until 1994. Presently he holds positions at both universities; adjunct professor at University of North Carolina and professor emeritus at the University of Alabama. Dr. Leinfelder has published more than 275 papers on restorative materials, authored more than 150 scientific presentations, two textbooks on restorative systems and has lectured nationally and internationally on clinical biomaterials.

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1. The glass ionomer cement (GIC) was developed by which of the following investigators?
   a. Black
   b. Kent
   c. Buonocore
   d. Brännstrom

2. The primary component of glass ionomer cement is which of the following?
   a. SiO2
   b. PCA
   c. ZnO2
   d. PMMA

3. Which of the following agents have been added to GIC for the purpose of enhancing their handling characteristics?
   a. Fortify
   b. PCA
   c. Resin
   d. NaF

4. Which is the best restorative material to use for pediatric patients with a moderately high caries rate?
   a. Amalgam
   b. Composite
   c. Compomer
   d. Glass ionomer

5. Which restorative material is associated with the greatest progression of clinical caries?
   a. Amalgam
   b. Composite resin
   c. Silicate cement/glass ionomer
   d. Porcelain

6. The use of a surface penetrating agent (Fortify, Bisco) will enhance the wear-resistant characteristics of both composite resins and glass ionomers. The amount of reduction in occlsual wear is approximately:
   a. 10 percent
   b. 20 percent
   c. 40 percent
   d. 100 percent

7. The clinical effectiveness of Fortify on glass ionomer restorations is due to which of the following?
   a. Generation of a copolymer
   b. Creation of a hard glassy surface
   c. Penetration and filling of subsurface spaces
   d. Development of a surface with a lower coefficient of friction

8. The correlation of wear generated either clinically or by means of the UAB in vitro wear device is quite high. The average difference between the two is no more than how many microns per year?
   a. 0
   b. 3
   c. 10
   d. 20

9. The avoidance of post-operative sensitivity can be attributed to which of the following conditions:
   a. Matched coefficients of thermal expansion between the tooth structure and the cement
   b. Reduction in electrical current
   c. An increase in pressure on the odontoblastic process
   d. Conservative use of zinc phosphate cement

10. In the case of minimal pulp exposure, the ideal agent recommended for the application to the surface of the exposure is?
    a. Glass ionomer
    b Calcium hydroxide
    c. Acid-etching agent
    d. Dentin bonding agent

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