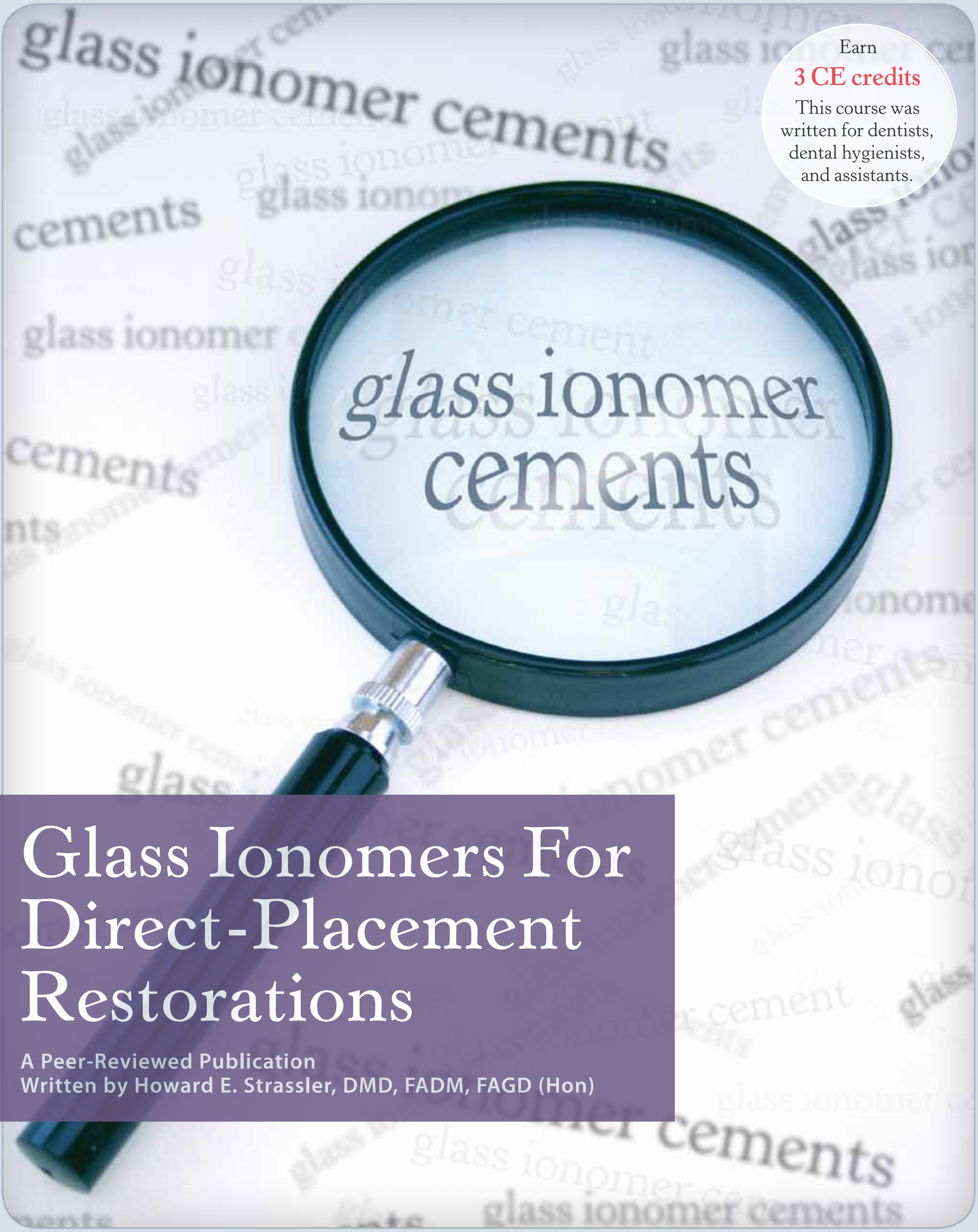

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Glass Ionomers For Direct-Placement Restorations

A Peer-Reviewed Publication

Written by Howard E. Strassler, DMD, FADM, FAGD (Hon)

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Educational Objectives

The overall goal of this course is to provide the reader with information on glass ionomer cement restoratives. Upon completion of this course, the reader will be able to do the following:

1. List the two types of chemistries used for the setting reaction of glass ionomer cements.
2. Describe the mechanism of action for the adhesion of glass ionomer cements to tooth structure.
3. List and describe the benefits of fluoride provided by glass ionomer cements.
4. List the restorative clinical indications for a direct-placement glass ionomer cement.

Abstract

Glass ionomer cements are self-adhesive to enamel and dentin, provide for caries-protective fluoride release at the margins of restorations, can be recharged with fluoride and are moisture tolerant. They are unique restorative materials that are available in several chemical and physical formulations that in turn determine their clinical uses.

Introduction

Glass ionomer cements (GIC) are unique restorative materials with many uses in clinical practice. What differentiates GIC from other restoratives is their chemistry, which allows them to be self-adhesive to enamel and dentin and provide for caries-protective fluoride release at the margins of restorations, as well as their ability to have the fluoride within their chemical matrix recharged by outside exposure to other fluoride-containing materials. Other unique features include their moisture tolerance, allowing GIC to be used for a wide variety of clinical applications. This article will provide the clinician with an overview of the advantages of GIC for direct-placement restorations that are based upon their chemistry and physical properties. Also, while this article is focused on direct-placement GIC for restorations, the different formulations, adhesive properties, differences in chemistries and viscosities for placement, physical properties, and appearance provide for a wide range of clinical uses for GIC that allow them to be used as a liner, base, luting cement, sealant and surface restorative material.

Chemistry of glass ionomer cements

GIC are classified according to their chemical formulation into two categories: conventional (or traditional) and resin-modified.[1] Conventional glass ionomer cements undergo a chemical self-setting acid-base reaction created by mixing an ion-leachable (fluoride ion) fluoroalumino-silicate glass (powder) with an aqueous polyacrylic acid or polycarboxylate acid (liquid). This advancement combined the advantages seen with early silicate cements (chemically leachable (fluoride ion) fluoroaluminosilicate glass [powder] and phosphoric acid [liquid]) and the adhesive properties of zinc polycarboxylate cements (zinc-oxide [powder] and polyacrylic acid [liquid]). This first type of GIC was developed by Wilson and Kent.[2] These changes and developing a higher-viscosity, thicker mix with the chemistry of conventional GIC resulted in improvements in tensile strength, compressive strength and fracture toughness; greater wear resistance and higher fluoride release were also achieved.[3]

Conventional glass ionomer cements generally have relatively poor physico-mechanical properties and are more prone to wear when compared to composite resins, and they have a very slow self-setting reaction. Preliminary finishing could not be done for 10 minutes and final finishing had to wait for at least 24 hours.[3,4] Conventional GIC used as tooth-colored restorative materials also have poorer esthetics compared to composite resin. In order to expand the clinical uses of GIC, resin was added to the formulation. This resin-modified glass ionomer cement (RMGI) chemistry was enhanced with the addition of water-soluble photopolymerizable resin monomers, 2-hydroxyethyl-methacrylate (HEMA) to the acidic cement liquid, and for powder-liquid RMGI some manufacturers use proprietary resin formulations.[1,5,6,7] The change in formulation of RMGI allowed them to be dual-cured: self-setting and light-cured. When compared to conventional GIC, resin-modified glass ionomers provide for improved physico-mechanical properties, resistance to early contamination by moisture, less microleakage, and improved adhesion to enamel and dentin combined with significant improvement in esthetic properties.[1,6,8,9,10,11] One recent modified formulation includes more resin as well as nanoparticles (Ketac Nano, 3M ESPE). In an effort to improve physical properties for GIC as a posterior restorative, manufacturers also developed metal-reinforced glass ionomers by adding silver amalgam alloy powder to GIC (Ketac Silver, 3M ESPE; Miracle Mix, GC America).

Table 1. Comparison of selected physical properties of resin-modified glass ionomers (RMGI), conventional glass ionomers (GIC) and hybrid composite resins (CR)

Property	RMGI	GIC	CR
Compressive strength	Med	Low-Med	Med-High
Flexural strength	Med	Low-Med	Med-High
Flexural modulus	Med	Med-High	High
Wear resistance	Med	Low	High
Fluoride release	Med-High	Med	None
Fluoride recharge	Med-High	High	None
Setting shrinkage	Low-Med	Low	Med
Esthetics	Good	Acceptable	Excellent

Adapted from: Powers J. Preventive materials. Resin Composite Restorative Materials. In Craig's Restorative Dental Materials. Powers JM, Sakaguchi RL. Mosby Elsevier. 2006; pp. 161-188; pp.189-212.

Clinical recommendations for these products are for use as long-term temporary restorations for caries control, to seal access openings of endodontically treated teeth, for core build-ups where at least 50% of the tooth structure was remaining, and for restoring primary teeth. These materials are not recommended as definitive restorations for the permanent dentition in stress-bearing areas because they do not have the wear resistance and resistance to chemical erosion of amalgam or composite resin.

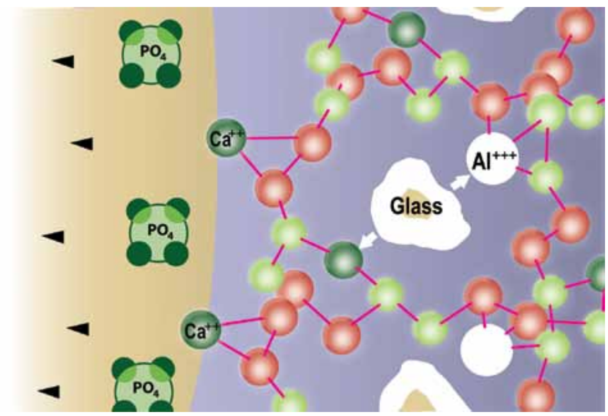
Contact with water during the initial placement and early setting of conventional glass ionomers can cause inhibition and delay in the setting reaction. It is critical to the clinical procedure that at the time of placement of the glass ionomer the dentin at the dentin-restorative interface be moist, and not desiccated, to ensure good adhesion. RMGI have reduced moisture sensitivity and are more moisture tolerant.[1] For powder-liquid RMGI, the proportion of self-setting acid-base reaction in RMGI is a minor part of the setting reaction. This change in reaction kinetics contributes to a dual-cured (self-setting and light-cured) reaction that provides RMGI with rapid setting and greater color stability.[1] In deeper restorations where the light intensity is compromised, the continued polymerization by self-setting of the resin-modified glass ionomer occurs over time.[12] For most resin-modified glass ionomers, it is recommended that the material be placed in increments no greater than 2 mm and each increment be light-cured. Paste-paste RMGI formulations are available where use of a product-specific cavity cleanser/primer is required before placement of the restorative material. The cavity cleansers/primers for RMGI are similar to those used for conventional GIC: i.e., a polyacrylic cavity cleanser is used to remove the smear layer.

Recently, a zinc-reinforced glass ionomer (Chemfil Rock, Dentsply) has been introduced that is formulated with a zinc-containing glass that provides reinforcement. This new zinc-reinforced glass ionomer is different from past resin -modified and conventional glass ionomer chemistries. It offers improved fluoride release, combined with a novel acrylic acid copolymer that improves wear resistance, flexural strength and fracture toughness. The high-viscosity, non-sticky formulation is mixed with a mechanical mixer in a syringeable capsule, which makes it easier to manipulate and pack, and features faster setting with improved physical properties for use in posterior teeth. It is also more moisture tolerant than conventional glass ionomers and has a radiopacity consistent with good readability in radiographs. Unlike earlier-generation resin-modified and conventional glass ionomer cements, the novel chemistry eliminates the need for two steps that have been required in the past – pretreatment with a cavity cleanser and surface coating of the glass ionomer after placement. Its physical property enhancements allow for greater durability when placing the material in posterior teeth and for pediatric applications in deciduous posterior teeth.[13]

Mechanism of adhesion of glass ionomer restoratives

Both GI and RMGI are self-adhesive to enamel and dentin. The mechanism of adhesion is an ionic bond between the glass ionomer and the calcium within the tooth structure.[1,4,5] (Figure 1) The adhesion of RMGI is slightly different; it forms a modified hybrid zone with the tooth structure.[3,4] When using RMGI to increase the bond to enamel, it is recommended that the enamel be beveled and a weak organic acid, the cavity cleanser/conditioner that is provided with the material, be used. Recent evidence for RMGI demonstrates that even though phosphoric acid etching is not recommended by manufacturers because it dissolves and removes the calcium, resulting in weaker and compromised adhesion, the resin/etched dentin/enamel interface will still demonstrate adhesion.[14,15] The use of cavity cleansers (polyacrylic acid) gently dissolves and removes the dentin and enamel smear layers without removing the calcium in the tooth that is important for the self-adhesion of glass ionomers (in contrast to etching, which results in removal of tooth structure for micromechanical retention of composites).

Figure 1. Mechanisms of adhesion for glass ionomers



Source: Adapted from Burgess JO. Compend Contin Educ Dent. 2008; 29:82-94.

The bond to dentin with glass ionomers is predictable. In clinical studies, retention of RMGI used to restore non-carious cervical notched lesions (NCCL) was greater than 90% at three years.[16] Retention of conventional GIC at ten years has been reported at 83% for similar restored lesions.[17] When shear bond strength to dentin has been evaluated it has been noted that when stressed there is a cohesive fracture of the glass ionomer, leaving the glass ionomer still bonded to the dentin.[18,19] Recent research with the new generation zinc-reinforced glass ionomer demonstrates adhesive interfaces similar to that seen with resin-modified glass ionomer.

When restoring Class V non-carious cervical lesions with RMGI, it was found that the dentin should be lightly roughened and prepared with a rotary instrument to create a uniform dentin smear layer and clean dentin surface. It is also important to use a cervical matrix to provide for 100%

leak-free restorations.[12] Clinically the cervical matrix allows the material to be adapted to the margins of the preparation under pressure as compared to adapting the restorative with a hand instrument, which can have the tendency to pull the restorative away from the margin. Another study investigated marginal adaptation of RMGI and recommended that restorations be finished in a separate appointment to allow for water sorption to improve marginal adaptation.[20] Whenever placing Class V restorations, potential contamination with sulcular fluid or moisture is a risk factor. It has been reported that when bonding RMGI to slightly moist dentin the restorative material exhibits moisture tolerance with no reduction in shear bond strength.[21]

Fluoride release of glass ionomer restoratives

A critical property for GIC that makes them unique and desirable is their ability to release fluoride from the glass fillers to adjacent tooth surfaces. Water, one of the constituents of GIC, is part of the acid-base reaction for setting; the water also plays a critical role in the fluoride release of GIC.[21] The aqueous phases of the set GIC exist in the form of hydrogels that allow a chemical equilibrium with an ion movement between the GIC and the environment – the oral cavity and the surrounding tooth structures.[22,23] It has been shown that fluoride-releasing materials are effective in inhibiting demineralization while providing for the remineralization of adjacent tooth structure.[24,25] This has important implications for GIC as restorative and preventive materials. When resin-modified glass ionomer cement was compared to amalgam for Class II restorations in primary molars, the RMGI exhibited less recurrent caries at the margins.[26] These primary molars had been restored with amalgam or RMGI three years earlier and were then collected for evaluation when exfoliated. The teeth were sectioned and the demineralization at the margins was evaluated using polarized light microscopy. It was found that the gingival margin of the amalgam restorations demonstrated demineralization of $2.16 \times 10^2 \pm 5.48 \times 10^2$ when compared to RMGI restorations with demineralization of $4.87 \times 10^4 \pm 2.65 \times 10^4$. The RMGI had significantly less adjacent demineralization than the amalgam ($P<.0001$).[26] Other studies have investigated the potential for RMGI to inhibit enamel demineralization on interproximal surfaces.[27,28,29] These findings suggest that RMGI enhance the prevention of enamel demineralization not only on the restored teeth but on the adjacent teeth as well. The mechanism of prevention may be twofold: remineralization of the adjacent tooth structures to the GIC restoration due to the fluoride, and the cariostatic properties of GIC that may affect bacterial metabolism.[30] These findings have important implications for patients with caries risk factors.[4]

How effective is the fluoride release over time? GIC have been described as a "smart" restorative material because the fluoride they contain is not only released to surrounding tooth structure but can also be recharged in the glass ionomer.[31,32,33,34] This is referred to as the "reservoir effect" and is an important feature of GIC.[5] GIC release fluoride from the unreacted glass fillers over time into the saliva. From the saliva there is an ion exchange that occurs, with the fluoride ions diffusing from the GIC (area of high concentration) to the tooth (lower fluoride concentration). Over time there is an equilibrium as the fluoride is incorporated into the hydroxyapatite crystals of the enamel and dentin, over an area of approximately 1-3 mm surrounding the restoration, forming hydroxyfluorapatite. Recharging of the GIC with fluoride in the unreacted glass ionomer filler can be accomplished with fluoride-containing oral care products, including topical fluoride gel applications, fluoride-containing toothpastes and mouth rinses.[4,35,36,37] This recharging effect allows GIC to retain their caries protective abilities.

Glass ionomer restoratives for direct placement restorations

Glass ionomer cements have many clinical uses. (Table 2) In recent years there have been significant improvements to glass ionomer cements that allow them to be used for routine restorations and provisional restorations. Glass ionomer cements can be used to successfully restore both permanent and primary teeth based upon these clinical implications.

Table 2. Clinical applications for direct-placement glass ionomer restoratives

Class V restorations
Caries control as provisional restorations
Blockout of undercuts in crown and onlay preparations
Dentin substitute as a base material
Small core/foundation build-ups where at least 50% of the tooth structure is remaining
Posterior restorations in primary teeth
Temporary restoration of endodontic access preparations
Temporary restorations anterior/posterior teeth
Non-stress-bearing restorations
Repair adjacent to crown margins due to subgingival caries
Repair of endodontic root perforations
Repair of external root resorptive lesions

Class V restorations

When there is excellent access to the gingival margins, RMGI can be used effectively for moderately deep and deep Class V NCCL in need of restoration; shallow, moderate and deep Class V NCCL with dentin hypersensitivity; and Class V carious lesions. For the patient with moderate-sized notch-shaped lesions on the cervical surfaces of anterior and

posterior teeth that exhibit dentin hypersensitivity, RMGI are indicated because of their more esthetic appearance when compared to conventional GIC and because placement of Class V etch-and-rinse adhesive composite resin restorations can be problematic to highly sensitive root surfaces.[38,39] Use of glass ionomers also eliminates the multiple steps for placement required with composite resin.[40] When using RMGI to restore NCCL lesions it is recommended that the dentin and enamel surfaces be cleaned with a pumice-water paste and that the enamel be beveled before restoration. For patients at high caries risk presenting with multiple Class V carious lesions, RMGI with fluoride release offer an advantage over composite resin. In recent years we have seen an increase in cervical caries and root sensitivity. Gingival recession of 3 mm or more has been reported to be present in at least 22% of the adult population in one or more teeth,[41] placing these patients at risk for dentin hypersensitivity of the exposed root surfaces as well as root caries.[42] Additionally, the baby boomers have a 30% likelihood of having recession on one or more teeth. Also, patients that have had or are having periodontal therapy are at risk of dentin hypersensitivity at rates of 55% after periodontal therapy (scaling and root planing and periodontal surgery).[42] According to recent reports of adults over the age of 60, almost 32% had root caries or a restored root surface. There are also many medications that contribute to xerostomia, which also increases caries risk in general.[43,44]

The earliest forms of RMGI were powder-liquid formulations; they had a low viscosity and could be difficult to place and adapt in the cavity preparation with a hand instrument. Dispensing of RMGI for restorations has improved with the use of predose capsules that are activated and mixed using mechanical mixers. Cervical matrices with a variety of shapes and sizes for anterior teeth, premolars and molars provide for ease of placement for resin-modified glass ionomers, as well as for better marginal adaptation than using hand instruments.[45] These cervical matrices can also be used for composite resins. (Figure 2)

Recently, paste-paste RMGI have been introduced that are easier to mix and place without any change in the physical properties. From this author's experience the latest generation of paste-paste RMGI are also more translucent appearing than past RMGI. These paste-paste RMGI are dispensed from double-barreled syringes onto a mixing pad and require conventional mixing of the pastes on the mixing pad using a cement spatula. This author would then load the RMGI into dispensing tubes and apply the RMGI into the cavity preparation. A recent innovation was the development of an automixing predose capsule for placement of the paste-paste nanoparticle resin-modified glass ionomer formulation. This automix-quick mix capsule offers the benefits of significantly fewer air bubbles and voids in the restoration and improved wear resistance, and the nanotechnology provides for better polishability compared to other resin-modified glass ionomers on the market.

Case report: Class V restoration

A 29-year-old male patient with multiple Class V carious lesions (Figure 3) and high caries risk was treatment planned for restoration of these lesions with self-mixing nanoparticle RMGI (Ketac Nano Quick). The teeth were anesthetized with local anesthesia. For this patient, the use of a dental dam was not possible because of the multiple preparations and limited access to the preparations that gingival retraction retainers would allow. The teeth were prepared using a #35 inverted cone bur. (Figure 4) The use of inverted cone burs is preferred because of their shorter length when compared to 330 burs to reduce the risk of the gingiva being lacerated during use of the bur in Class V preparations at or beneath the free margin of the gingiva.

After completion of the cavity preparations, the corresponding one-part light-cure cavity primer was applied to the cavity preparations (Figure 5), air dried and light-cured for 10 seconds using a high-intensity LED curing light. The function of the primer is to wet the surfaces of the cavity preparation to facilitate adhesion of the restorative material.

Figure 2a. Cervical matrices

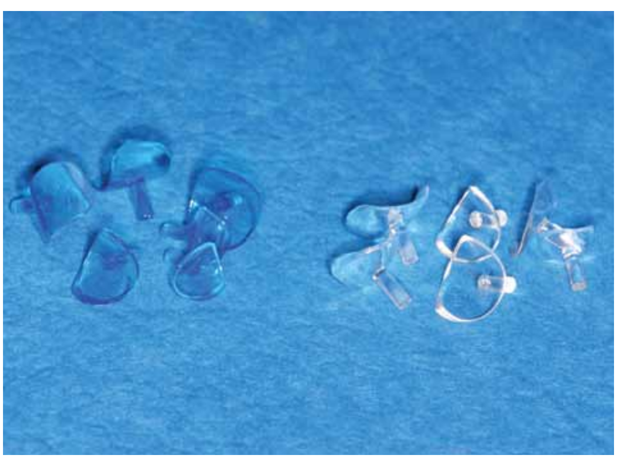


Figure 2b. Application of cervical matrix

The restorative material was applied into the preparations with an automixing capsule (Figure 6). A cervical matrix that flexes to fit the contour of the tooth and minimizes excess of restorative materials for easier finishing was used to adapt and shape the restoration before light curing. The restoration was light-cured for 20 seconds with the high-intensity LED light curing unit. The restorations were then ready for finishing and polishing. (Figure 7)

Figure 3. Patient with multiple Class V carious lesions

Figure 4. Cavity preparations

Figure 5. Application of light-cured primer

Figure 6. Self-mixing capsule

Figure 7. Finished restorations

Class V carious lesions

There has been a rise in the presence of "meth mouth" rampant caries, cases where isolation and control of the soft tissue can be very difficult.[46] (Figure 8) Also, for many patients, access with a curing light to the distal and lingual surfaces of posterior teeth is not possible due to tooth position and angulation of the curing light tip. For patients with recurrent caries at the margins of existing crowns and bridges where replacement of the restoration is not feasible, salvaging these restorations by restoring and repairing the margins with GIC is a viable choice. For cases where the margins of the restoration will be subgingival due to caries, access to root surfaces is difficult and consideration should be given to new-generation high-viscosity conventional glass ionomer cements. These glass ionomers are more moisture tolerant and will set and bond in a compromised field.[47]

Figure 8. Meth mouth

Caries control and provisional restorations

With the acceptance of total resin adhesion for most restorative procedures, there has been a desire to eliminate eugenol-containing restoratives in the management of dental emergencies for deep and large carious lesions in vital teeth requiring intermediate, provisional restorations to maintain pulp vitality. This treatment of deep caries in vital teeth without pulpal invasion has been referred to as caries control. Caries control is also indicated for single-visit treatment of multiple teeth with extensive caries to stabilize the active disease or as a diagnostic tool to evaluate pulpal response and symptoms after treatment. Reinforced zinc oxide and eugenol (ZOE) temporary restorations were for many years the material of choice for these deep carious lesions because the eugenol has a sedative effective on the pulp. Unfortunately, these temporary restorations, due to the presence of residual eugenol-infiltrated dentin after the removal of the ZOE restorations, have been shown to be detrimental to the setting reactions of composite resin restorations because they inhibit polymerization.[48] Dentin containing residual eugenol can have a negative impact on the resin adhesion of definitive restorations. Since ZOE restoratives also do not bond to tooth structure they require retentive undercuts which requires additional tooth removal. An alternative to the use of ZOE temporary restoratives for caries control is the new-generation zinc-reinforced self-adhesive one-step GIC. Conventional GIC have also become popular for the temporary restoration of endodontic access preparations during endodontic treatment because they are self-adhesive and will not contaminate the enamel or dentin, thus allowing for later use of a composite resin.

Case report: salvaging teeth with multiple carious lesions

A 79-year-old male patient presented with numerous teeth with root caries that were subgingival. (Figure 9) He was at high caries risk due to medication-induced xerostomia and had inadequate oral hygiene. For many of the teeth, pulp testing indicated pulp vitality but there was concern that the size and depth of the preparations might lead to the need for endodontic treatment. The patient did not want endodontic treatment. Control of the operatory field was difficult and some of the preparations were going to be subgingival. It was decided to place long-term provisional restorations with zinc-reinforced glass ionomer cement (Chemfil Rock). The carious mandibular second molar was prepared with a #35 inverted cone bur. (Figure 10) No pretreatment is required for this glass ionomer. The capsule was activated by pushing the plunger against a tabletop until the plunger overlap was less than 2 mm. (Figure 11) The capsule was then mixed for 15 seconds using a microprocessor-controlled restorative mixer that provides for consistent mixing. The working time for zinc-reinforced glass ionomer is 90 seconds. The capsule was loaded into the extruder and the trigger activated until the glass ionomer paste was extruded from the capsule tip. The glass ionomer paste was syringed and adapted in the cavity preparations. (Figure 12) The GIC was allowed to set undisturbed. This new zinc-reinforced glass ionomer does not require a special surface coating during the setting reaction. Six minutes after activation and mixing, the glass ionomer was finished with finishing diamonds (Figure 13) and stones using a slow-speed handpiece. Finishing was completed using an aluminum oxide finishing point in a slow-speed handpiece. (Figure 14)

Figure 9. Root caries on the mandibular second molar

Figure 10. Preparation of carious lesions

Figure 11. Capsule activation

Figure 12. Syringing the restorative into the Class V cavity preparations

Figure 13. Finishing the gross excess with a flame-shaped 50 micron fine finishing diamond

Figure 14. Completed long term glass-ionomer provisional restorations

Case report: caries control

As stated earlier, GIC can be used for the management of dental emergencies in vital teeth with deep and large carious lesions requiring intermediate, provisional restorations that are placed to evaluate and maintain pulp vitality and for caries control. The vitality of the tooth should first be determined by pulp testing, radiographic evidence and patient history (presence and type of symptoms). For the patient in this case, the symptoms of short-duration pain on the carious mandibular first molar were consistent with reversible pulpitis. (Figure 15) The decision was to perform caries control and reevaluate the tooth in four to six weeks. Local anesthesia was administered and a dental dam placed. The caries was removed using a dentin-safe, caries-removing polymer bur to avoid the potential for a mechanical pulpal exposure.[49] There was no evidence of caries exposure. (Figure 16) The preparation was restored with zinc-reinforced GIC (Figure 17) and polished with a finishing abrasive point. (Figure 18) The completed restoration provides for a well-sealed provisional restoration. (Figure 19)

Figure 15a. Radiographic view of deep carious lesion, mandibular first molar

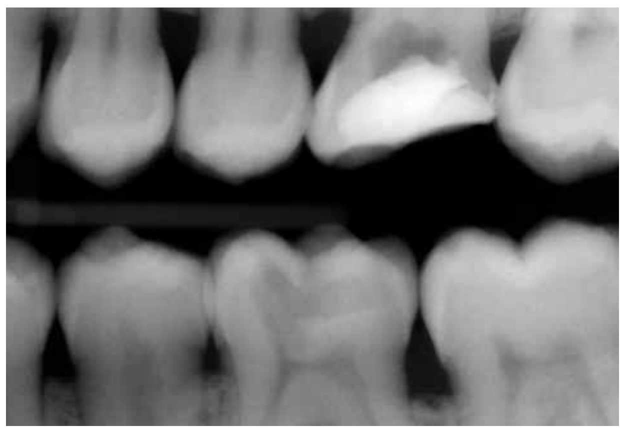


Figure 15b. Clinical view of deep carious lesion, mandibular first molar

Figure 16. Preparation with complete caries removal

Figure 17a. Placement of restorative material with syringe capsule

Figure 17b. Adaptation of restorative material to preparation margins

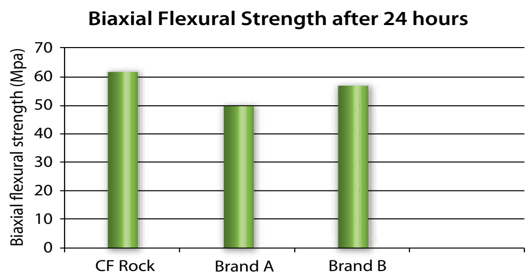
Figure 18. Finishing the restoration

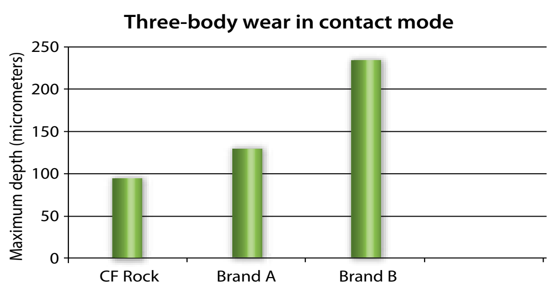
Figure 19. Completed caries control restoration

Pediatric posterior restorations

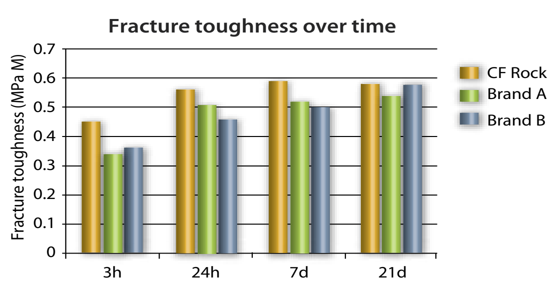
Glass ionomer cements are excellent restorative materials for deciduous (primary) posterior teeth.[50,51] Since primary teeth will be exfoliated to allow for eruption of the permanent successors, the restoration does not have to be as wear resistant as with permanent teeth. Also, primary enamel is less wear resistant than permanent enamel, amalgam and composite resin.[52,53] The recently introduced zinc-reinforced glass ionomer demonstrates properties desirable for primary tooth posterior restorations. (Figure 20)

Figure 20. Graphs showing comparative physical properties





Latta M, Creighton University (2009)



Lohbauer U, University Medical Center of Erlangen (2009)

When treating children, fewer clinical treatment steps will provide for improved results. A significant benefit of this zinc-reinforced glass ionomer is that there is no need for pretreatment cavity cleanser or for a coating to be placed over the restorative material until it reaches full setting in 5-10 minutes. It is a single-step, self-adhesive restorative material.

Glass ionomer sealants

Resin-based sealants are highly effective at preventing pit and fissure caries on posterior teeth.[54] A review of the evidence in ten studies of sealants preventing pit and fissure caries demonstrated that sealants reduced dental caries by 78% at one year and 59% at four or more years of recall.[55] For at-risk patients, once the posterior tooth has erupted in the mouth, it is recommended that the occlusal surfaces be sealed within 6 months to 1 year.[54,55] Dennison and coworkers investigated retention of sealants on at-risk teeth that were fully erupted against those that were partially erupted.[56] Three years after resin sealant placement, it was found that fully erupted, sealed teeth required 0% replacements, while teeth that had had gingival tissue at the level of the distal marginal ridge at the time of sealant placement had a 26% sealant replacement rate. When the gingival tissue was *over* the distal marginal ridge at the time of placement, the replacement rate was 54%. Clearly, isolation of field and access contribute to resin sealant success.

Here lies the dilemma – clinicians want to seal pits and fissures when permanent teeth are first erupting, when isolation is very difficult or impossible. (Figure 21) Resin adhesion to etched enamel requires a clear, dry enamel surface. Recent research has investigated the use of glass ionomer cements for sealant placement because they offer an advantage over resin sealants for semi-erupted teeth in that they are moisture tolerant and adhere to the enamel surface through ionic bonding (and not through micromechanical retention following acid etching).[57,58,59,60,61] These clinical trials have found that the use of glass ionomer sealants on newly erupted first molars was successful. In one evaluation of sealants, it was found that unsealed first molars had a 2.1 times higher chance of developing dentinal lesions after 5 years than first molars that were sealed using a GIC sealant when they were newly erupted.[58] These studies demonstrated that GIC sealant retention is significantly lower after 1 year than resin-based sealants.[57-61] This author would recommend that once the tooth is fully erupted, the glass ionomer sealant can be replaced when it needs to be with a resin sealant. This is consistent with the concept that all sealants need to be reevaluated and maintained. If there is partial or complete loss of sealant, the clinician needs to reapply the sealant.

Using glass ionomer pit and fissure sealant (Fuji Triage, GC America) offers significant benefits when sealing an erupting posterior tooth. This has been shown to be able to be used predictably on newly erupted or semi-erupted teeth because it can be used in a moist field.[62] The glass ionomer pit and fissure sealant allows for fluoride release to the surrounding tooth structure and also has a semipermeable surface to allow the calcium and phosphate ions that are present in saliva to pass through the sealant and combine with the fluoride to produce remineralization of the enamel as a fluorapatite. Another unique characteristic of a glass ionomer is that it provides for a high burst of fluoride for remineralization combined with a prolonged fluoride release over time. If the patient is following the recommendation to use a fluoride toothpaste, then the patient is recharging the glass ionomer with new fluoride ions every day. Following good clinical techniques will assure clinical success with glass ionomer as a sealant. (Figure 22)

Figure 21. View of mandibular second molar with soft tissue over the distal surface

Figure 22. Glass ionomer sealant after placement

Image courtesy of Dr. Mark Grebosky

Conclusion

While not as esthetic as composite resins, there are specific clinical situations where glass ionomers are the materials of choice for restoring teeth. In recent years glass ionomer cements as direct restorative materials have become more user

friendly with improved physical properties. Glass ionomer cements that are designed for posterior use include RMGI, conventional glass ionomer cements, zinc-reinforced glass ionomer cement and specialized glass ionomers for sealants. Glass ionomer cements can also play an important role in restoration to control rampant caries.

The unique chemistry of a glass ionomer that allows the release of fluoride and recharge with fluoride has important clinical implications for patients at risk for caries and with carious lesions.

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Author Profile

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Questions

1. The chemistry of a GIC allows it to _____.
   a. be self-adhesive to enamel and dentin
   b. provide for caries-protective fluoride release
   c. recharge with fluoride
   d. all of the above

2. Early silicate cements contained _____.
   a. fluoroaluminosilicate glass
   b. phosphoric acid
   c. hydrochloric acid
   d. a and b

3. Zinc-oxide and polyacrylic acid are contained in _____.
   a. zinc phosphate cement
   b. zinc oxide cement
   c. glass ionomer cement
   d. zinc polycarboxylate cement

4. The first type of glass ionomer cement was developed by _____.
   a. Thatcher and Kent
   b. Thatcher and Bent
   c. Wilson and Bent
   d. Wilson and Kent

5. Compared to composites, conventional glass ionomer cements generally have _____.
   a. relatively poor physico-mechanical properties
   b. relatively poor biological properties
   c. less resistance to wear
   d. a and c

6. Resin-modified glass ionomer cement was developed by adding chemistry was enhanced with the addition of _____ to the formulation of conventional GIC.
   a. water-soluble photopolymerizable resin monomers
   b. 2-hydroxyethylmethacrylate
   c. alkaline phosphatase
   d. a and b

7. A resin-modified glass ionomer is _____.
   a. dual-cured
   b. self-setting
   c. light-cured
   d. all of the above

8. Metal-reinforced glass ionomers were developed by adding _____ to GIC.
   a. gold alloy powder
   b. silver amalgam alloy powder
   c. iron oxide particles
   d. all of the above

9. The setting shrinkage of glass ionomer cement is _____ composite resin.
   a. higher than for
   b. the same as for
   c. lower than for
   d. none of the above

10. The fluoride release of a resin-modified glass ionomer is _____.
    a. always lower than with a composite resin
    b. always negligible compared to with a conventional glass ionomer
    c. always higher than with a composite resin
    d. not clinically relevant

11. Glass ionomer cements are not recommended as definitive restorations for the permanent dentition in stress-bearing areas because they do not have _____.
    a. the wear resistance of amalgam
    b. the wear resistance of composite resin
    c. the resistance to chemical erosion of amalgam or composite resin
    d. all of the above

12. Contact with water during the initial placement and early setting of conventional glass ionomers can cause _____.
    a. the setting reaction to be accelerated
    b. the setting reaction to be delayed
    c. the setting reaction to cause extensive shrinkage
    d. none of the above

13. For powder-liquid RMGI, the proportion of self-setting acid-base reaction in RMGI is a _____.
    a. minor part of the setting reaction
    b. major part of the setting reaction
    c. factor in polymerization shrinkage
    d. all of the above

14. For most resin-modified glass ionomers, it is recommended that the material be placed in increments no greater than _____ deep.
    a. 1 mm
    b. 2 mm
    c. 3 mm
    d. 5 mm

15. _____ is used to remove the smear layer prior to placement of glass ionomer cements.
    a. 35% phosphoric acid etchant
    b. Acetic acid cleanser/conditioner
    c. Polyacrylic acid cleanser/conditioner
    d. all of the above

16. Zinc-reinforced glass ionomer is combined with a novel acrylic acid copolymer that improves _____.
    a. wear resistance
    b. fracture toughness
    c. flexural strength
    d. all of the above

17. Zinc-reinforced glass ionomer has a _____ consistent with good readability in radiographs.
    a. radiopacity
    b. radiolucency
    c. translucency
    d. all of the above

18. Pretreatment with _____ is necessary for zinc-reinforced glass ionomer cement.
    a. acid etchant
    b. polyacrylic acid conditioner
    c. basic phenol
    d. none of the above

19. _____ require pre-treatment with a cavity cleanser.
    a. Conventional glass ionomer cements and zinc-reinforced glass ionomer cements
    b. Resin-modified glass ionomer cements and zinc-reinforced glass ionomer cements
    c. Conventional glass ionomer cements and resin-modified glass ionomer cements
    d. none of the above

20. The mechanism of action for adhesion of glass ionomer cements to enamel is _____ between the glass ionomer and the _____ within the tooth structure.
    a. a molecular bond; hydrogen
    b. a molecular bond; calcium
    c. an ionic bond; calcium
    d. none of the above

21. When using RMGI to increase the bond to enamel, it is recommended that the enamel be _____.
    a. removed
    b. etched
    c. beveled
    d. any of the above

22. The bond to dentin with glass ionomers is _____.
    a. unpredictable
    b. predictable
    c. poor
    d. a and c

23. When shear bond strength to dentin has been evaluated it has been noted that when stressed there is a _____.
    a. separation of the glass ionomer from the dentin
    b. aggressive fracture of the enamel
    c. cohesive fracture of the glass ionomer
    d. a or c

24. When restoring Class V non-carious cervical lesions with RMGI, it was found that the dentin should be _____.
    a. lightly smoothed
    b. lightly roughened
    c. prepared with a rotary instrument to create a uniform dentin smear layer
    d. b and c

25. Whenever placing Class V restorations, potential contamination with _____ is a risk factor.
    a. moisture
    b. sulcular fluid
    c. cellular defects
    d. a and b

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Questions

26. Water _____ GIC.
    a. plays a critical role in the fluoride release of
    b. is part of the acid-base reaction for setting
    c. is one of the constituents of
    d. all of the above

27. When resin-modified glass ionomer cement was compared to amalgam for Class II restorations in primary molars, the RMGI exhibited ____ at the margins.
    a. less recurrent caries
    b. the same level of recurrent caries
    c. more recurrent caries
    d. none of the above

28. Findings suggest that RMGI enhance the _____.
    a. prevention of enamel demineralization on the restored teeth
    b. prevention of enamel demineralization on adjacent teeth
    c. prevention of remineralization
    d. a and b

29. _____ can be used to recharge the GIC with fluoride.
    a. Topical fluoride gel applications
    b. Fluoride-containing toothpastes
    c. Fluoride-containing mouth rinses
    d. all of the above

30. Placement of Class V etch-and-rinse adhesive composite resin restorations_____.
    a. is preferred
    b. can be problematic
    c. is suitable for fluoride release
    d. allows for improved recharging of fluoride

31. Gingival recession of 3 mm or more has been reported to be present in at least _____ of the adult population in one or more teeth.
    a. 12%
    b. 17%
    c. 22%
    d. none of the above

32. In Class V preparations, the use of inverted cone burs is preferred because of the _____.
    a. reduced risk of over-preparing the cavity
    b. reduced risk of lacerating the tongue
    c. reduced risk of lacerating the gingiva
    d all of the above

33. The function of the primer is to _____.
    a. wet the surfaces of the cavity preparation
    b. facilitate adhesion of the restorative material
    c. acid etch the enamel
    d. a and b

34. A flexible cervical matrix is used to _____.
    a. fit the contour of the tooth
    b. minimize excess of restorative materials for easier finishing
    c. adapt and shape the restoration before light curing
    d. all of the above

35. For many patients, access with a curing light to the distal and lingual surfaces of posterior teeth is not possible due to _____.
    a. tooth position
    b. angulation of the curing light tip
    c. inadequate lighting
    d. a and b

36. The treatment of deep caries in vital teeth without pulpal invasion has been referred to as _____.
    a. endodontic control
    b. caries control
    c. prophylactic filling
    d. none of the above

37. Reinforced zinc oxide and eugenol was for many years the material of choice for temporary restorations for deep carious lesions because it _____.
    a. synthesizes an external stimulus
    b. awakens the pulp
    c. has a sedative effect on the pulp
    d. none of the above

38. Reinforced zinc oxide and eugenol (ZOE) temporary restorations _____.
    a. inhibit polymerization
    b. can have a negative effect on resin adhesion
    c. do not bond to tooth structure
    d. all of the above

39. Zinc-reinforced glass ionomer does not require _____.
    a. mixing
    b. pre-treatment with a conditioner
    c. a special coating during the setting reaction
    d. b and c

40. A _____ can be used to safely remove caries from dentin to avoid the potential for a mechanical pulpal exposure.
    a. caries-invading stainless steel bur
    b. sharp explorer
    c. caries-removing polymer bur
    d. none of the above

41. Primary enamel is less wear resistant than _____.
    a. permanent enamel
    b. amalgam
    c. composite
    d. all of the above

42. Resin-based sealants are _____ at preventing pit and fissure caries on posterior teeth.
    a. ineffective
    b. moderately effective
    c. highly effective
    d. none of the above

43. A review of sealants found that they reduced dental caries by _____ at one year.
    a. 58%
    b. 68%
    c. 78%
    d. 88%

44. Three years after resin sealant placement, it has found that fully erupted, sealed teeth required _______ replacements.
    a. 0%
    b. 5%
    c. 10%
    d. 15%

45. It has been found that if the gingival tissue was over the distal marginal ridge at the time of placement, the replacement rate was _______.
    a. 34%
    b. 44%
    c. 54%
    d. none of the above

46. Glass ionomer pit and fissure sealant _____.
    a. can be used predictably on newly erupted or semi-erupted teeth
    b. allows for fluoride release to the surrounding tooth structure
    c. offers significant benefits when sealing an erupting posterior tooth
    d. all of the above

47. In recent years glass ionomer cements as direct restorative materials have _____.
    a. become more user friendly
    b. offered improved physical properties
    c. encompassed several types of reinforced glass ionomers
    d. all of the above

48. Glass ionomer cements are now available that are _____.
    a. resin-modified
    b. metal-reinforced
    c. zinc-reinforced
    d. all of the above

49. Glass ionomer cements can also play an important role in _____.
    a. restoring hopeless teeth
    b. controlling rampant caries
    c. controlling periodontal disease
    d. all of the above

50. The release of fluoride and recharge with fluoride is part of the unique chemistry of a _____.
    a. composite resin
    b. glass ionomer cement
    c. silicate cement
    d. all of the above

ANSWER SHEET

Glass Ionomers For Direct-Placement Restorations

Name: ____________________ Title: __________ Specialty: __________

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Telephone: Home (   ) ____________ Office (   ) ____________ Lic. Renewal Date: __________

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Educational Objectives

1. List the two types of chemistries used for the setting reaction of glass ionomer cements.
2. Describe the mechanism of action for the adhesion of glass ionomer cement to tooth structure.
3. List and describe the benefits of fluoride provided by glass ionomer cement.
4. List the restorative clinical indications for a direct-placement glass ionomer cement.

Course Evaluation

Please evaluate this course by responding to the following statements, using a scale of Excellent = 5 to Poor = 0.

1. Were the individual course objectives met? Objective #1: Yes No Objective #2: Yes No Objective #3: Yes No Objective #4: Yes No

2. To what extent were the course objectives accomplished overall? 5 4 3 2 1 0

3. Please rate your personal mastery of the course objectives. 5 4 3 2 1 0

4. How would you rate the objectives and educational methods? 5 4 3 2 1 0

5. How do you rate the author's grasp of the topic? 5 4 3 2 1 0

6. Please rate the instructor's effectiveness. 5 4 3 2 1 0

7. Was the overall administration of the course effective? 5 4 3 2 1 0

8. Do you feel that the references were adequate? Yes No

9. Would you participate in a similar program on a different topic? Yes No

10. If any of the continuing education questions were unclear or ambiguous, please list them.

____

11. Was there any subject matter you found confusing? Please describe.

____

____

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____

____

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3.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	28.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
4.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	29.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
5.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	30.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
6.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	31.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
7.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	32.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
8.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	33.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
9.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	34.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
10.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	35.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
11.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	36.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
12.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	37.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
13.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	38.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
14.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	39.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
15.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	40.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
16.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	41.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
17.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	42.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
18.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	43.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
19.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	44.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
20.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	45.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
21.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	46.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
22.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	47.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
23.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	48.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
24.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	49.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
25.	Ⓐ	Ⓑ	Ⓒ	Ⓓ	50.	Ⓐ	Ⓑ	Ⓒ	Ⓓ

AGD Code 253, 017

PLEASE PHOTOCOPY ANSWER SHEET FOR ADDITIONAL PARTICIPANTS.

AUTHOR DISCLAIMER

The author(s) of this course has/have no commercial ties with the sponsors or the providers of the unrestricted educational grant for this course.

SPONSOR/PROVIDER

This course was made possible through an unrestricted educational grant. No manufacturer or third party has had any input into the development of course content. All content has been derived from references listed, and or the opinions of clinicians. Please direct all questions pertaining to PennWell or the administration of this course to Machele Galloway, 1421 S. Sheridan Rd., Tulsa, OK 74112 or macheleg@pennwell.com.

COURSE EVALUATION and PARTICIPANT FEEDBACK

We encourage participant feedback pertaining to all courses. Please be sure to complete the survey included with the course. Please e-mail all questions to: macheleg@pennwell.com.

INSTRUCTIONS

All questions should have only one answer. Grading of this examination is done manually. Participants will receive confirmation of passing by receipt of a verification form. Verification forms will be mailed within two weeks after taking an examination.

EDUCATIONAL DISCLAIMER

The opinions of efficacy or perceived value of any products or companies mentioned in this course and expressed herein are those of the author(s) of the course and do not necessarily reflect those of PennWell.

Completing a single continuing education course does not provide enough information to give the participant the feeling that s/he is an expert in the field related to the course topic. It is a combination of many educational courses and clinical experience that allows the participant to develop skills and expertise.

COURSE CREDITS/COST

All participants scoring at least 70% on the examination will receive a verification form verifying 3 CE credits. The formal continuing education program of this sponsor is accepted by the AGD for Fellowship/Mastership credit. Please contact PennWell for current term of acceptance. Participants are urged to contact their state dental boards for continuing education requirements. PennWell is a California Provider. The California Provider number is 4527. The cost for courses ranges from $39.00 to $110.00.

Many PennWell self-study courses have been approved by the Dental Assisting National Board, Inc. (DANB) and can be used by dental assistants who are DANB Certified to meet DANB's annual continuing education requirements. To find out if this course or any other PennWell course has been approved by DANB, please contact DANB's Recertification Department at 1-800-FOR-DANB, ext. 445.

RECORD KEEPING

PennWell maintains records of your successful completion of any exam. Please contact our offices for a copy of your continuing education credits report. This report, which will list all credits earned to date, will be generated and mailed to you within five business days of receipt.

CANCELLATION/REFUND POLICY

Any participant who is not 100% satisfied with this course can request a full refund by contacting PennWell in writing.