How to reduce composite polymerization shrinkage associated with direct posterior composites

Technique uses packable posterior glass ionomer

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As the practice of dentistry has advanced over the years, our patients have become more aware of the options available for the restoration of their teeth. Many are now attending their dentist with a request that amalgam no longer be used in their mouth. At the same time, many cannot afford some of the more expensive indirect restorations that are indicated when placing old amalgam restorations. Consequently, large direct composites are often placed in difficult situations, with the results often being less than ideal. Most of the problems associated with direct posterior composite are the result of composite polymerization shrinkage, and to circumvent this problem, indirect restorations are placed allowing for "preshrinking" of the restoration in the laboratory. However, indirect restorations require the conversion of the retentive cavity form associated with amalgams, into a non-retentive one, with the associated, unnecessary loss of additional sound tooth structure.

In this article, I would like to present a technique using GIC-composite that I feel will diminish the potential difficulties associated with direct posterior composite. It has been my experience that this technique offers a predictable and more cost effective alternative for indirect restorations.

Composite polymerization shrinkage is the source of most of the common problems associated with direct posterior composites. Uncontrolled shrinkage leads to the formation of micro-gaps, which present as white lines at the margins, stained margins, post-insertion sensitivity, and recurrent caries. The deleterious effects of composite shrinkage can be exacerbated by the cavity volume, cavity configuration (C-factor) and boundary conditions. When changing from the regular use of amalgam to the use of composite in posterior teeth, a lack of understanding of the concepts associated with incremental placement techniques, and the effects of composite shrinkage and how to control composite shrinkage vectors, leads to problems with post-insertion sensitivity, and the dentist becomes disillusioned with direct placement techniques.

Approximately 90% of composite shrinkage occurs within the first five minutes of curing, with an additional 10% occurring after this period. Shrinkage vectors are difficult for the dentist to control, and become more important as composite volume increases with increasing cavity size. Post-insertion sensitivity immediately after placement of direct posterior composites is most often due to the formation of a micro-gap between the composite and the underlying dentin, as a result of the composite polymerization forces exceeding the dentin bond strength. The symptoms are similar to those of a cracked tooth, with the patient reporting hot and cold sensitivity, and pain on chewing. The only solution is to replace the restoration, and use a technique that will preserve the integrity of the restorative-dentin bond.

Current research is attempting to develop a direct restorative that is capable of bulk placement because it does not shrink, with the goal being to avoid the polymerization shrinkage stresses that adversely affect the tooth-restoration seal. Equally, development of self-etching dentin bonding agents has occurred in an attempt to solve some of the problems associated with direct resin bonding to dentin. A material with these properties has been available for many years, yet has not been widely recognized. Auto-cure glass ionomer cement (GIC) is a self-etching dentin bonding restorative material with bulk placement capability. When composite is combined with auto-cure GIC (the GIC-Composite Co-cure technique), in conjunction with an understanding of polymerization and bonding dynamics, a restoration is created that utilizes each of the materials’ strengths, and minimizes their weaknesses. The biomimetic properties of glass ionomer combine with the advantages of composite to create a restoration that is superior to either of the individual materials.

Recent in-vivo studies have reported a degradation of the composite resin-dentin tensile bond strength by approximately 50% per year over a three-year period. Conversely, the GIC-dentin bond appears to be stable, with ionic adhesion creating an improved micro-leakage seal in comparison to resin dentin bonding. The GIC-Composite Co-cure technique recognizes and addresses the many problems associated with direct posterior restorations, resulting in predictable, aesthetic restorations.
In the co-cure technique, GIC is also used to reduce the volume of the cavity by replacing all the lost dentin, and reducing the composite volume so it only replaces lost enamel. As auto-cure GIC sets, it shrinks as much as composite (approximately 3%). However, the shrinkage occurs slowly in relation to the development of the dentin bond, with shrinkage stress being relieved by flow within the mass of the GIC. As a consequence, the stress placed on an auto-cure GIC dentin bond is 2-3Mpa, compared to up to 18Mpa in light-cured composites. Most resin dentin bonding studies are performed on extracted, non-vital teeth, with the bonds being created on buccal dentin just under the DEJ. This provides the ideal situation for high in-vitro test bond strengths with the dentin tubules lying perpendicular to the cut surface and the tubules not being filled with vital odontoblast processes. It is erroneous to extrapolate these in-vitro studies to the reality of bonding to dentin in old, extensive amalgam cavities that have less than ideal dentin substrate to bond to. The dentin can be infiltrated with amalgam corrosion by-products, it may be hyper- or hypomineralized, it may be remineralized carious dentin, or the dentinal tubules may be obliterated by secondary dentin. None of these situations is ideal for resin dentin bonding, and the bond that is created will only ever be weaker than those created in the laboratory.

Of equal importance, resin bonding into deep proximal boxes, that have little or no enamel at the margin, can be problematic, due to the lack of enamel onto which to bond (poor boundary conditions), high C-factor, large volume, and a dentin tubule orientation that is less than ideal. Resin dentin bonding does not have the integrity or strength of an enamel-resin bond. As a consequence, without a well-developed enamel resin bond to protect the peripheral margins, the underlying resin dentin bond is exposed to micro-leakage and bond degradation.

Auto-cure GIC is a self-etching dentin bonding material that creates not only a micro-mechanical bond, but also a chemical bond at the hybrid zone. The poly-acrylic acid in the mixed auto-cure GIC mobilizes the ionic constituents of the GIC, including fluoride, and at the same time, calcium and phosphate are mobilized from the underlying dentin. As the reaction reaches its completion, the pH begins to rise and a hybrid zone develops that is comprised of the constituents of both the GIC and the dentin. This zone is more acid resistant than either the GIC or the underlying tooth surface, even though it contains no resin. The modern reinforced auto-cure GIC’s exhibit compressive strengths similar to dentin, though their tensile strengths are lower than dentin. The GIC co-cure restoration is designed to place compressive forces on the GIC base and protect the GIC from tensile forces. When a GIC restoration fails, there is a cohesive failure of the restoration, rather than adhesive debonding from the underlying dentin. Originally, GICs were used in a sandwich technique where the GIC was cut back after it had been allowed to set, prior to placement of the composite layer. In this technique, the GIC was acid-etched and resin bonded, creating a micro-mechanical link between the GIC and the overlying composite. This type of bond, however, is relatively weak, and can occasionally lead to delamination of the composite from the underlying GIC.

The original GIC-Co-cure technique was described by Dr G. Knight. This technique recognized the need to create a chemical bond between the GIC and composite, and more importantly, to create a dentin bond that was not resin-based. The co-cure concept also recognized the significant problems associated with composite shrinkage and led to the concept of polymerising the composite on top of a still unset GIC base. This prevented the stresses associated with composite shrinkage from being transferred to the dentin-restoration interface. The technique described in this article is a modification of the original procedure, and considers aesthetic requirements, as well as further enhancing control of composite shrinkage.

Principles involved in the GIC-Composite co-cure restoration:

- GIC creates a predictable, self-etching chemical dentin bond, resulting in the absence of micro-leakage at the interface. Stability of the hybrid zone appears to be enhanced when GIC is overlayed with composite in a laminate technique.

- The GIC is used to reduce the volume of the cavity so that overlying composite volume is reduced to a point where the problems associated with composite shrinkage are reduced.

- The composite is wet bonded to the underlying GIC with a resin modified GIC (Fujibond). The resin component of Fujibond chemically links with the overlying composite and the GIC component bonds with the underlying auto-cure GIC. The bond that is created is stronger than the individual materials.

- Resin bonding to phosphoric acid etched enamel, and auto-cure GIC bonding are two of the most predictable bonds available in dentistry today. The Co-cure technique utilizes both bonds, with the goal being to capitalize on the strengths, and minimize the weaknesses, of both materials.

- Composite is bulk packed over the underlying unset GIC and sectioned with a fine instrument to create sections of composite that touch the underlying GIC and only one axial wall of the cavity. When polymerized, these sections of composite shrink towards the tooth rather than towards the curing light due to their low C-factor.

- The technique creates a laminated restoration that more resembles natural tooth structure. The composite replaces enamel, the intermediate bonding layer of Fujibond and flowable composite mimic the DEJ, and the auto-cure GIC replaces dentin.

- Note that there are no resin dentin bonding agents used in this technique. Dentin bonds are GIC in origin, and enamel bonds are either GIC or unfilled BisGMA resin.
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Figure Legends:
These images have been captured on a typhodont, and a dark shade of composite used, to allow visualization of the technique.

Technique description
Cavity design

The cavity design needs to emphasize the retention of sound tooth structure. These restorations are often used to replace old restorations where outline forms have already been established. Modification of cavities for direct adhesive restorations require reshaping of the enamel margins, to ensure there are no undercut enamel rods, and to create a bevel in areas of the margins that do not have enamel prism ends exposed. Ensure clean dentin is available in the floor of the cavity to allow for the formation of stable bonds. 22,23,24 Internal line angles need to be rounded to help prevent deleterious stress concentration.

Knowledge of enamel prism orientation in various areas of the tooth is required for predictable resin bonding to etched enamel. 25, 26 A half U-shaped bevel on the occlusal edge, particularly in the region of the marginal ridge, created with a small, fine, round polishing diamond, will result in exposure of the ends of enamel prisms (Fig. 1).

Axial margins of proximal boxes need to be bevelled to remove unsupported enamel. However, no bevel is required on the floor of the cavity because it is restored with auto-cure GIC, which creates a chemical bond to any remaining enamel, rather than the mechanical bond associated with resin bonding. Often, in deep cavities, there is no remaining enamel for resin bonding. Refinement of the cavity with air abrasion helps identify any fractured enamel at the margins, removes the smear layer created by tooth preparation, and is very effective in removing amalgam corrosion products.

Restorative methodology

Once a matrix has been placed and stabilized to create a sound contact point, the restoration can be placed. Initially, the dentin is conditioned with 10-20% polyacrylic acid for 10-15 seconds (Fig. 2). This is then rinsed off, and the enamel margins are etched with 37% phosphoric acid for 15-20 secs. The enamel margin at the bottom of the proximal box does not require etching with phosphoric acid because it will be covered with GIC (Fig. 3).

At this point, it is important to understand the difference between bonding with resin, compared to bonding with GIC. For enamel, resin bonding requires that the ends of supported enamel prisms are exposed, and resin bonding to dentin requires the removal of mineral content to expose the collagen matrix. Because GIC is a self-etching bonding agent, it only requires the removal of the dentin smear layer, or light conditioning of the enamel with 10% polyacrylic acid for 10-15 seconds.

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A capsule of reinforced auto-cure GIC, such as Fuji TRIAGE, is mixed and injected into the bottom of the proximal box and onto the occlusal floor. Apart from the floor of the proximal box, the goal is to replace dentin with GIC, and enamel with resin. The GIC in the proximal box is kept below the contact point (Fig. 4).

The auto-cure GIC is placed with a microtip brush (Microbrush Corporation) dipped into a lining consistency mix of Fujibond (Fig. 5). This is a resin-modified GIC designed for bonding. It is used primarily as a lubricant to aid in manipulation of the Fuji TRIAGE, and it also creates the chemical link between the underlying GIC and the overlying composite. It is also the dentin bonding agent that is used to cover exposed areas of dentin that cannot be covered with Fuji TRIAGE. The microtip brush, or any other instrument that is being used to manipulate the Fuji TRIAGE, should NEVER be dipped in unfilled resin to act as lubricant. This has the potential to allow resin onto a dentin or enamel surface, which would then prevent the GIC ionic bond from establishing, and would guarantee micro-leakage because of the lack of any bond. This will result in post-insertion sensitivity, and the potential for recurrent caries.

Once the Fuji TRIAGE has been manipulated into place, unfilled BisGMA resin is wiped around the previously etched enamel margins to establish the enamel-composite bond that is required later in the restoration process (Fig. 6).

A thin layer of flowable composite is then injected onto the unset Fuji TRIAGE (Fig. 7). This is then light-cured. This polymerization cycle also sets the unfilled resin on the enamel. The underlying auto-cure GIC is still unset, but the layer of set flowable composite allows for the placement of a bulk of posterior micro-hybrid composite without causing displacement of the Fuji TRIAGE.

A second thin layer of flowable composite is then placed, and posterior micro-hybrid composite is bulk-packed directly onto the unset flowable composite (Fig. 8). The second layer of flowable is placed to prevent the creation of voids between the cavity walls and the high viscosity micro-hybrid composite.

This bulk pack of composite is now sectioned with a fine bladed composite instrument (Hu-Friedy CIGFT Mini 3) (Fig. 9). The goal is to create segments that only touch one wall of the cavity and the underlying GIC. As a rule of thumb, the sectioning pattern follows the fissure pattern of the tooth. If in doubt, simply place more sectioning grooves to ensure that opposing walls are not connected by composite. As the composite polymerizes, each section of composite will tend to shrink towards the tooth, due to its low C-factor.

Once the composite has been polymerized, the sectioning grooves are filled with flowable composite, (Fig. 10) and a further increment of composite is packed down into the grooves to express the flow-
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able composite (Fig. 11). The final volume of composite placed in the sectioning grooves is very low, resulting in minimal polymerization stresses on the margins.

The restoration is covered with glycerine, or a similar agent, to exclude oxygen and reduce the oxygen-inhibited layer during final photo-polymerization. After removing the matrix, cure the restoration from both the lingual and buccal surfaces. After contouring and polishing, the exposed interproximal Fuji TRIAGE must be protected from moisture contamination for 24 hrs by painting the surface with a varnish. If you use resin, there is a chance you will close up the contact area and the patient will not be able to floss (Fig. 12).

**Modifications of the technique for slot preparations**

For slot preparations, it is not necessary to place the layers of flowable composite. The composite is placed directly onto the Fuji TRIAGE once it has been manipulated into place with the Fujibond. Wipe unfilled BisGMA resin on the etched enamel, and then place the composite, working it from the occlusal enamel margins towards the matrix. This will prevent the Fuji TRIAGE extruding up onto the occlusal margins. Because of the small volume of composite in these restorations, it only needs one sectioning groove placed mesio-distally through the composite, down to the underlying GIC.

**Figure 9.** Composite is now bulk-packed and contoured onto the second wet flowable layer, using the higher viscosity composite to express the flowable composite. The composite is sectioned along the fissure pattern of the tooth, using a very fine composite plastic instrument. Further sectioning can be done to ensure no section of composite is touching more than one wall of the cavity. All occlusal extensions need to be sectioned to their length. The composite is then polymerized. Using this technique, the composite has been sectioned into 10 increments that have all been cured at once, rather than placing 10 separate increments that have to be cured individually.

**Figure 10.** Wet the sectioning grooves with flowable composite.

**Figure 11.** Using the sectioning instrument, pack composite into the grooves, expressing the excess flowable composite. This prevents voids in the grooves.

**Figure 12.** The restoration is covered with clear gel or glycerin, to reduce oxygen inhibition, and then polymerized. The matrix is removed, the restoration contoured and polished and then exposed GIC (interproximal) is covered with a layer of cavity varnish.

**Conclusion**

This article has described the GIC-composite co-cure technique, which is designed to address the difficulties associated with direct posterior resin restorations, and provide a predictable alternative to many indirect restorations. As experience is gained with this technique, it is easily extended into cusp overlays and the direct replacement of a lost cusp.

Due to space constraints the bibliography for this article can be found at www.dentaltown.com.

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Dr Graeme Milicich resides and practices in New Zealand. He lectures internationally on various topics including biomechanics, minimally invasive dentistry, caries risk assessment, prevention and control, and restorative techniques, based on the utilization of glass ionomers in combination with composites, using a modified co-cure technique. He is currently President Elect of the World Congress of Microdentistry, an international organization devoted to education on minimally invasive dentistry.

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