

Bioactive materials support proactive dental care

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Resin bonding of the human dentition has become a "standard" in the United States and Canada. There are more than 80 different bonding systems on the market today. We have seen them evolve through multiple generations in an attempt to "simplify" the bonding process. Yet, as these agents have simplified, many in our profession have seen many challenges arise.

A significant number of reports in the literature have been showing that the "immediate bonding effectiveness of contemporary adhesives are quite favorable, regardless of the approach used [however] in the long term, the bonding effectiveness of some adhesives drops dramatically."¹ The hydrophilicity that both etch-and-rinse and self-etch bonding agents offer initially in the dentin-bonding process becomes a significant disadvantage in terms of long-term durability.²

It is this hydrophilicity of simplified adhesive systems combined with other operator-induced

challenges that contribute to these failures. Tay, Carvalho, Pashley, et al. have reported repeatedly in the literature of this problem.^{3,4} They continue to report that these bonding agents do not coagulate the plasma proteins in the dentinal fluid enough to reduce this permeability. The fluid droplets contribute to the incompatibility of these simplified adhesives and dual-/auto-cured composites in direct restorations and the use of resin cements for luting of indirect restorations.

The term "water-tree" formation has been coined to describe this process, which originated from the tree-like deterioration patterns that were found within polyethylene insulation of underground electrical cables. It is now being applied to the water blisters formed by the transfer of dentinal fluid across the dentin-bonding interface. These "water blisters ... act as stress raisers and form initial flaws that cause subsequent catastrophic failure along the adhesive-composite interfaces."⁴

_c.e. credit part I

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(Photos/Provided by Dr. John C. Comisi unless noted otherwise)



Fig. 1



Fig. 2



Fig. 3



The previously mentioned plasma proteins are released by the dentin when subjected to acids and cause hydrolytic and enzymatic breakdown of the dentin and resin bonding agent interface.⁵ These enzymes are called matrix metalloproteinases (MMPs).

Currently, there are only three methods of reducing these MMPs: 2 percent chlorhexidine solutions that are used prior to application of bonding agents; etchants containing benzalkonium chloride, otherwise known as BAC (i.e., Bisco's Uni-etch products); and polyvinylphosphonic-acid-producing products (glass ionomer and resin-modified glass ionomers).

Due to the short efficacy of these chlorhexidine solutions being used before bonding, this methodology has come into question as of late.⁶ Etchants with BAC have been shown to be valuable in the reduction of MMPs and should be considered in all bonding processes.⁷ However, the most intriguing methodology of reducing MMPs and remineralizing tooth structure is with the use of glass ionomer cements (GIC) and resin-modified glass ionomers (RMGIC).

Glass ionomers and resin-modified glass ionomers

Glass ionomer cements have long been used as a direct restorative material. Their early formulations made the material difficult to handle, and the breakdown of the material made it an undesirable solution in dental restoration. However, these materials, especially in today's formulations and pre-encapsulated presentations, have many properties that make them very important in the restorative process.

The work at companies such as SDI North America (Riva product line), GC America (Fuji product line) and

VOCO (Iono product line) have continued to make great strides in improving these products for easier and longer-lasting use of GIC and RMGIC products.

First, these materials are bioactive, and up until recently, they were the only materials with this property; that is they have the capacity to interact with living tissue or systems. Glass ionomers release and recharge with ions from the oral cavity.

This transfer of calcium phosphate, fluoride, strontium and other minerals into the tooth structure helps the dentition deal with the constant assault of the acidic nature of day-to-day ingestion of food and beverages and encourages remineralization; and the incorporation of phosphorous into the acid in today's GICs creates polyvinylphosphonic acid.⁸

This property of GICs makes them a major agent in the reduction of MMP formation, and thereby minimizing if not eliminating the collagen breakdown commonly found in many resin-dentin bonding procedures.⁹

Second, they bond and ultimately form a union with the dentition by chemically fusing to the tooth. The combination of the polyacrylic acid and the calcium fluoroaluminosilicate glass typically found in GICs reacts with the tooth surface, which releases calcium and phosphate ions that then combine into the surface layer of the GIC and forms an intermediate layer called the "interdiffusion zone."¹⁰

No resin bonding agents are required due to this chemical fusing to the tooth structure. This ion release helps inhibit plaque formation and provides an acid buffering capability that helps to create a neutralization effect intraorally. In addition, these GICs have very good marginal integrity with better cavity-sealing properties, have better internal adap-



(Fig. 8/Provided by Brian Novy)

tion and resistance to microleakage over extended periods of time, have no free monomers, can be bulk filled and offer excellent biocompatibility.¹¹

Another important consideration is that GICs are moisture-loving materials, which makes them very sensible for use in the intraoral cavity.

The transfer of dentinal fluid from the tooth to the GIC essentially creates a "self-toughening mechanism of glass ionomer based materials ... serves to deflect or blunt any cracks that attempt to propagate through the matrix [and] ... plays an adjunctive role by obliterating porosities [which] delay the growth of inherent cracks in the GIC under loading."⁴

The intermediate layer of the GIC provides flexibility during functional loading and acts as a stress absorber at the interface of the restoration and the tooth.¹²

Resin-modified glass ionomers (RMGIC), which are a hybrid of traditional glass ionomer cements with a small addition of light-curing resin, exhibit properties intermediate of the two materials.¹³ This material has been shown to have properties similar to GIC, but with better esthetics and immediate light cure. RMGICs have been shown to undergo slight internal fracturing from polymerization shrinkage, yet have an inherent ability to renew broken bonds and reshape to enforce new forms.¹²

Application of RMGIC to all cut dentin in Class II composite restorations has been shown to "significantly reduce micro-leakage along (the) axial wall" of the restoration,¹⁴ and helps prevent bacterial invasion of the restored tooth. RMGIC biomaterials are

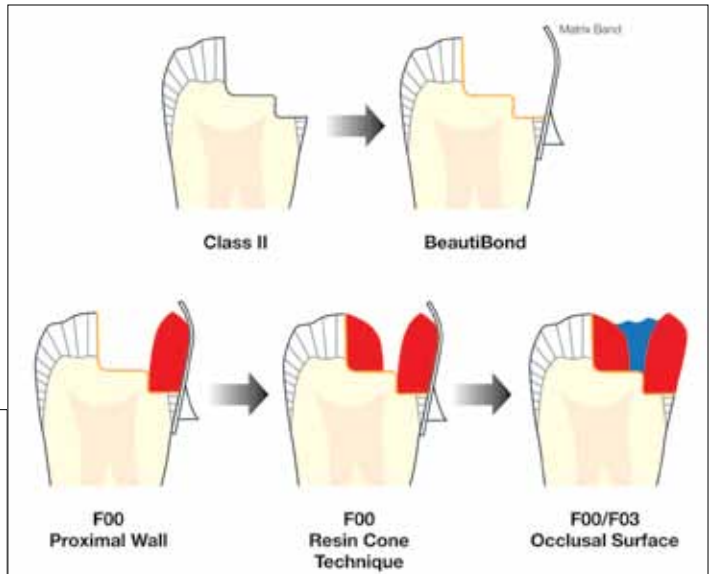
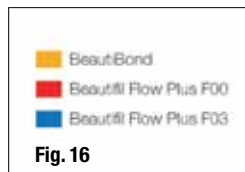
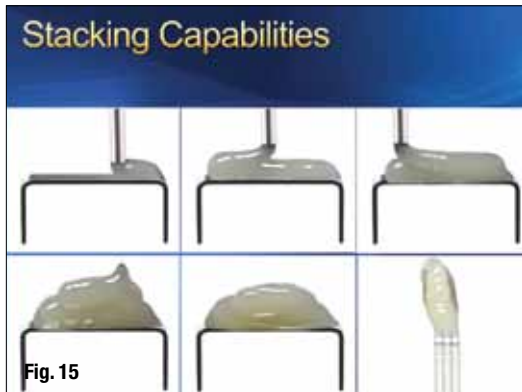
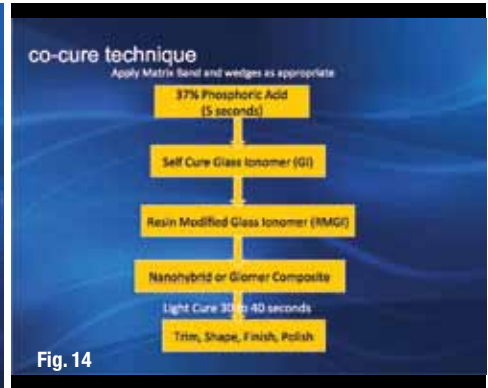
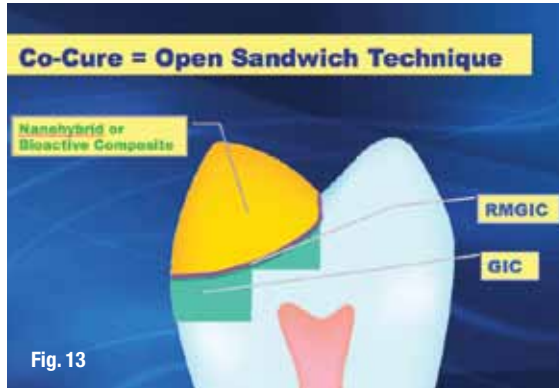
multifunctional molecules that can adhere to both tooth structure and composite resin, thus providing an improved sealing ability by chemical or micromechanical adhesion to enamel, dentin, cementum and composite resin.

They, like GICs, can be bulk filled to reduce the amount of composite necessary to restore the cavity preparation and act as dentin substitutes in the restoration.¹⁵

The use of GIC and RMGIC in the restoration of posterior Class V restorations and conservative Class I restorations provides many benefits. They are easy to place and reasonably forgiving, even in a slightly moist environment. They should be placed in a moist but not wet environment, so familiarity with technique is imperative as it is with all dental restorations. I will often use Riva SC (SDI) or Fuji 9 GP Extra (GC America) in posterior Class I and V restorations (Figs. 1–7).

Polishing and shaping of the materials must be done with water spray and fine/ultra fine composite finishing burs and polishers so as not to destroy the surface of the material (Fig. 8). The use of RMGIC products, such as Riva LC or Fuji II LC, is great in bicuspid and anterior Class V restorations, especially in high caries prone patients (Figs. 9–12).

Class II restorations, however, have always presented a challenge to the clinician. If the operator wanted to use GIC or RMGIC, there was no easy way to do this that appeared to provide satisfactory results. It is with this in mind that the "sandwich technique" was developed.



It was thought that using the properties of GIC to bond to the tooth and then applying resin-bonding agents and composite to the set GIC could help reduce sensitivity and bond failures typically seen in many resin-bonded composite (RBC) techniques.

Typically, the GIC is placed in the preparation, allowed to set, cut back to ideal form and then bonded to with an RBC technique. However, the inability of RBCs to adhere to the set GIC often creates many failures. The materials by themselves are incompatible over the long term.

The modified sandwich technique evolved as a means to overcome this problem. Placing RMGIC over set GIC – and then adding a RBC to that – provided a better solution, but was as laborious and time consuming to do, as is the sandwich technique.

–The 'Co-Cure Technique'

In 2006, an article was published¹⁶ that, in my opinion, has revolutionized the way I approach direct posterior restorations and direct restorations as a whole. The article presented a radical approach to direct posterior restorations, called the Co-Cure



Technique. This technique is defined as the simultaneous photo-polymerization of two different light-activated materials that involves "the sequential layering of GIC, RMGIC and composite resin prior to photo-polymerization and before the initial set of the GIC [which] enables an efficient single-visit placement of a [direct] restoration ..."¹⁶

In the Co-Cure Technique, the composite restoration does not require a bonding agent because the bonding agent is essentially the RMGIC. The RMGIC acts as the interface between the GIC and the com-

posite material. It combines the GIC, RMGIC and composite in a way to form what can best be described as a "monolithic biomimetic restoration."

This restoration is an "open sandwich" type of sandwich technique. That is, the GIC component is exposed to the oral environment (Fig. 13) at the gingival portion of the restoration. It is quickly and efficiently accomplished and has significantly reduced postoperative sensitivity compared with typical direct RBC techniques. I have been placing these types of direct posterior restorations since 2008. They have become the cornerstone of my practice.

Technique procedure (Fig. 14)

After placement of an appropriate dental matrix, the technique incorporates the use of 37 percent phosphoric acid to prepare the tooth for restoration. The acid is essentially "flooded" into the preparation in a similar manner to doing a "total-etch" RBC. It is, however, washed off after five seconds of placement. The tooth is then dried but not desiccated. The area remains slightly moist because the GIC that will be placed next is hydrophilic.

Fill the preparation with the triturated GIC material up to the level of the DEJ, then immediately place the triturated RMGIC in a very thin layer to cover the GIC and walls of the preparation. Finally, place the composite over the previous materials to slightly overfill the preparation. With a large round burnisher dipped in an unfilled resin material (i.e., Riva Coat by SDI or G-Coat by GC), wipe away the excess GIC and composite restoration material to create your margins and prevent ditching and white lines.

The occlusal table of the restoration can then be compressed gently with a plastic occlusal matrix by either having the patient bite or by the operator pressing gently with his thumb or forefinger to improve the coalescence of the three materials. This can help reduce the time involved in creating the final occlusion of the restoration by creating a functional occlusal table.

The restoration is then cured for 30 to 40 seconds with an LED curing light that generates at least 1,500 mw/cm². Appropriate light output is critical for all direct cured restorations, and assurance that appropriate output is provided by the curing light is needed for complete cure of any direct restoration.

The restoration is evaluated for complete cure and then a layer of an unfilled resin is placed on the exposed GIC/RMGIC/composite complex and cured for an additional 10 seconds. The matrix band is removed and the restoration is trimmed and polished as any typical RBC restoration would be.

I have found that an entire three-surface posterior restoration can be accomplished in less than three minutes once the matrix has been placed. Typically, finishing the restoration can also be done in less than

three minutes. This makes the direct posterior restoration quite efficient and beneficial to the clinician and the patient because we are providing a restoration that will help enhance healing of the dentition and reduce recurrent decay and restorative failure.

_ Nanotechnology in dental materials

Nanotechnology involves the production of functional materials and structures in the range of 0.1 to 100 nanometers by various physical or chemical methods. Today, the development of nanotechnology has become one of the most highly energized disciplines in science and technology because it can stimulate the creation of many new materials with previously unimagined applications and properties.

Several studies^{17,18} have shown that the inclusion of these types of nano-fillers and nano-fibers into the dental materials (dental composites and bonding agents) can improve the physical properties by increasing the strength, polishability, wear resistance, esthetics and bond strengths in many dental applications.

It is also envisioned that the incorporation and utilization of these nanoparticles in the form of nanorods, nanofibers, nanospheres, nanotubes and ormocers (organically modified ceramics) into dental restorative and bonding agents can create more biomimetic (life-like) restorations. This will not only enable these materials to mimic the physical characteristics of the tooth structure, but will also be able to facilitate the remineralization of that structure.

As Saunders states in his conclusion, "such nanorestorative biomaterials could very credibly be the next transformative clinical leap" in restorative dentistry.

_ Giomers

In that vein, an exciting advancement in bioactive materials is the development of giomer products (Shofu Dental, Beautifil II, and Beautifil Flow Plus). These giomers are resin-based composites that contain pre-reacted glass ionomer particles (S-PRG). These particles are made of fluorosilicate glass reacted with polyacrylic acid (just like a GIC), just before being incorporated into the resin. This creates a new type of bioactive material.

These giomer products display properties in a manner similar to GICs¹⁹: They release ions and recharge with ions from the oral cavity, inhibit plaque formation and neutralize and buffer the acids of the mouth.²⁰

No other composite material has this property to date. I use these giomers instead of traditional nano-hybrid composites in my restorations because of these properties. They complete the entire

biomimetic and bioactive nature of all the co-cure procedures that I create.

The Beautifil Flow Plus product line has also expanded the way that I create restorations due to their unique viscosities. These materials can be stacked (Fig. 15) and used in a restorative process I call the "modified resin cone technique" (Fig. 16).

They can also be applied to create direct composite veneers that can be easily placed, sculpted and highly polished (Fig 17). Easy placement, the ability to stack and maintain position and shape, plus their bioactive nature, make these materials a "game changer."

_Resin-modified, light-cured bonding agents

Another advancement that I have been working with is a product that is a resin-modified, light-cured bonding agent (SDI, North America: Riva Bond LC). This product is a specially formulated liquid RMGIC that can be used to bond composite restorations in the traditional sense, used in traditional sandwich and modified sandwich techniques and, of course, used in the Co-Cure Technique.

This concept is especially appealing in light of the research that indicates RMGICs provide quite good marginal seal when used as a bonding agent on cut dentin surfaces.¹⁴ I especially like to use it with the Co-Cure Technique and when doing anterior restorations.

Using this technique I am able to get a completely biomimetic, bioactive restoration in both situations because of the bioactive nature of the materials used.

The technique for use of this RMGIC bonding agent with composite is as follows:

- 1) Etch with 37 percent phosphoric acid for five seconds.
- 2) Wash and dry but do not desiccate.
- 3) Triturate and apply the RMGIC bonding agent with a micro-brush and cure for 20 seconds.
- 4) Place composite to fill the preparation and cure as appropriate.

When I use this material in the Co-Cure Technique, I just substitute it for the traditional RMGIC material that I would have used otherwise.

_Resin-modified calcium silicates

Another recent interesting product release is from Bisco and is called TheraCal™ LC. This light-cured bioactive material is used to seal and protect the dentin-pulp complex. It is the first of a new class of internal pulpal protectant materials known as resin-modified calcium silicates (RMCS).

It acts as a pulp capping and liner material. Calcium hydroxide (CH) has been the "gold" standard for

pulp capping for many years. However, it has always had difficulties in use as a liner under RBC adhesives. In fact, despite their frequent use, the success of CH based therapies is only 30 to 50 percent.²¹

It has also been shown that traditional resin-based light-cured liners have been cytotoxic to cultured odontoblast-like cells, while light-cured resin-based MTA cements presented the lowest cytopathic effects.²² Based on this, the creation of light-cured RMCS is a logical step in developing a solution for direct pulpal protection.

Calcium has been shown to be crucial to the formation of apatite, dentin bridge formation and re-apatite potential of affected dentin. Additionally, alkalinity also seems to be contributory toward this goal. This combination in the RMCS material appears to form good, hard and thick dentin bridges and stimulates dentin pulp cells to turn into odontoblastic dentin cells.²³

This type of material represents a promising new direction in direct pulp-capping clinical procedures with its ability to form apatite and further contribute to the formation of new dentin.

_Conclusion

It is my belief that using bioactive materials in the provision of care for my patients has been paramount to the success of the care I have been providing. In this way, I have provided ways to heal the dentition, enhance the restoration and improve the health of my patients.

I believe we are on the threshold of further bioactive material advancements and that learning and incorporating these restorative materials into the day-to-day provision of care will continue to help our patients, our practices and our profession.

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