Bioactive materials support proactive dental care

Dr John C Comisi discusses bioactive materials

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 favourable, regardless of the approach used (however) in the long term, the bonding effectiveness of some adhesives drops dramatically.”1 The hydrophillicity 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 hydrophillicity 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.”5

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.6 These enzymes are called matrix metalloproteinases (MMPs).

Currently, there are only three methods of reducing these MMPs: two per cent chlorhexidine solutions that are used prior to application of bond-...
Glass ionomers and resin-modified glass ionomers

Glass ionomer cements have long been used as a direct restorative material. Their early formulations were based on the materials cementing ability by chemical or micromechanical retention. However, these materials, especially in today's formulations and 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 (lono 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 re-charge with ions from the oral cavity.

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

This property of GICs makes them a major agent in the re- duction of MMPs and formation, and thereby minimising if not elimi- nating the collagen breakdown commonly found in many resin- dentin bonding procedures.7

Second, they bond and ultimately form a union with the dentition by chemically fusing to the tooth. The combina- tion of the polyacrylic acid and the calcium fluoro-aluminio silicate glass typically found in GICs reacts with the tooth sur- face, which releases calcium and phosphate ions that then combine into the surface layer of the GIC and forms an inter- mediate layer called the “inter- diffusion zone.”90

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 neutralisation effect intraorally. In addi- tion, these GICs have very good marginal integrity with better cavity-sealing properties, have

Another important consider- ation is that GICs are moisture-loving materials, which makes them very sensible for use in the introral cavity. The transfer of dental 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 obliterat- ing porosities [which] delay the growth of inherent cracks in the GIC under-loading.”74

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 iono- mers (RMGIC), which are a hy- brid of traditional glass ionomer cements with a small addition of light-curing resin, exhibit properties intermediate of the two materials.78 This material has been shown to have prop- erties similar to GIC, but with better aesthetics and immediate light cure. RMGICs have been shown to undergo slight inter- nal fracturing from polymerisa- tion shrinkage, yet have an inher- ent ability to renew broken bonds and reshape to enforce new forms.75

Application of RMGIC to all cut dentin in Class II composite restorations has been shown to “significantly reduce micro-leak- age along the (axial) wall” of the restoration,7 and helps prevent bacterial invasion of the restored tooth. RMGIC biomaterials are multifunctional molecules that can adhere to both tooth struc- ture and composite resin, thus providing an improved sealing ability by chemical or microme- chanical adhesion to enamel, dentin, cementum and compos- ite 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.75

The use of GIC and RMGIC in the restoration of posterior Class V restorations and conserva- tive Class I restorations provides many benefits. They are easy to place and reason- ably 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 GF Extra (GC America) in posterior Class I and V restaura- tions (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 bicuspids and anterior Class V restorations, especially in high caries prone patients (Figs 9-12).

Class II restorations, how- ever, 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 pro- vide satisfactory results. It is with this in mind that the ‘sand- wich technique’ was developed.

It was thought that using the properties of GIC to bond to the tooth and then apply- ing 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 sand- wich technique.

The ‘Co-Cure Technique’ In 2006, an article was pub-lished7 that, in my opinion, has revolutionised the way I ap- proach direct posterior restora- tions and direct restorations as a whole. The article presented a radical approach to direct pos- terior restorations, called the Co-Cure Technique. This tech- nique is defined as the simul-taneous photo-polymerisation of two different light activated materials that involves “the sequential layering of GIC, RMGIC and composite resin pri- or to photo-polymerisation and before the initial set of the GIC [wich] enables an efficient sin- gle-step placement of a [direct] restora- tion…”78
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 composite 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 15) 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 (e.g., 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 50 to 40 seconds with an LED curing light that generates at least 1,500mW/cm². Appropriate light output is critical for all direct cured restorations, and assurance that appropriate output is provided by the curing light is needed.

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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 dentin 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 energised disciplines in science and technology because it can stimulate the creation of many new materials with previously unimagined applications and properties.

Several studies have shown that the inclusion of these types of nanofillers and nanofibres into the dental materials (dental composites and bonding agents) can improve the physical properties by increasing the strength, polishesability, wear resistance, aesthetics and bond strengths in many dental applications.

It is also envisioned that the incorporation and utilisation of these nanoparticles in the form of nano-rods, nano-fibres, nano-spheres, nano-tubes and nanomoles (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 remineralisation of that structure.

As Saunders states in his conclusion, “such nano-restorative 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 gioner products (SHOFU Dental, Beautifil II, and Beautifull Flow Plus). These gioners 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 gioner products display properties in a manner similar to GICs: they release ions and reharsh ions from the oral cavity, inhibit plaque formation and neutralise and buffer the acids of the mouth.

No other composite material has this property to date. I use these gioners 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 Beautiful 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 (SDF, 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 research that indicates RMGICs provide quite good marginal seal when used as a bonding agent on cut dentin surfaces. 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 biocompatible, bioactive restoration in both situations because of the bioactive nature of the materials used.

**Conclusion**

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.

Editorial note: A complete list of references is available from the publisher.

**About the author**

Dr John C Comisi, DDS, MAGD, has been in private practice in Ithaca, NY, since 1985. He is a graduate of Northwestern University Dental School and received his Bachelor of Science in biology at Fordham University. He is a member of the American Dental Association and its associate organisations, the Academy of General Dentistry, the American Equilibration Society, the International and American Association of Dental Research, a research associate at New York University Dental School and an editorial board member of Dental Products Shopper Magazine. Comisi is a Master of the Academy of General Dentistry, and holds fellowships in the American College of Dentists, Pierre Fauchard Academy and the International College of Dentists. He may be contacted at jcomisi@comisi.com. (Photos provided by Dr John C Comisi unless noted otherwise.)