BIOACTIVE MATERIALS

Clinical choice or clinical necessity?

by Dr. John Comisi

John Comisi, DDS, MAGD, has been in private practice in Ithaca, New York since 1983, and is president and CEO of Sleep Focused Solutions. He is the founder of Dental Care with a Difference, PC and an assistant professor at the Medical University of South Carolina College of Dental Medicine. He is a graduate of Northwestern University Dental School, a master of the Academy of General Dentistry, and holds Fellowships in the Academy of Dentistry International, the American College of Dentists, the Pierre Fauchard Academy, and the International College of Dentists.

A need for a new technique

The restoration of tooth structure damaged by dental caries or trauma has been the goal of the dental profession for more than 100 years. Although there have been many solutions, there is always the desire to find a better one. The placement of direct restorations is the bread and butter of general dental practices, and these restorations can often preserve healthy tooth structure and provide immediate results for patients. However, we need to recognize that our current hybridization and restorative methods may ultimately be flawed.

A study by the National Institute of Dental and Craniofacial Research reported the average life expectancy of composite restorations is 5.7 years and that the primary cause of failure is the degradation of the bonding agent at the material/tooth interface.[1] Multiple generations of resin bonding-adhesion systems have been developed to overcome shortcomings of previous ones; different particle fillers and monomers have been added to resin composite materials in an attempt to enhance them, and simpler forms of dental adhesives have been developed. However, even with the advances in resin-based sciences, the problems at the adhesive/tooth interface persist. Considering the trend to replace amalgam with composites, and the failure rate of composite restorations being double to that of amalgam, the consequences could be detrimental to our patients.[2,3]

The dental literature is filled with calls to action for the development of materials and techniques to reverse this trend, and it is imperative that we understand why there's a need to change how we provide care for our patients.[1,4]

CASE STUDIES

CASE 1

A 37-year-old patient presented for treatment after years of neglect. After administering anesthetic and placing an Isolite isolation device, we prepared teeth #10–12 and restored them with Activa Bioactive-Restorative composite.

Fig. 1: *Preoperative image of #10–12.*

Fig. 2: *#10 and #11 prepared with Bioclear Diamond Wedges in place to protect the gingival tissue.*

Fig. 3: *#10 has been restored and #11 is ready to be restored using Blue View VariStrip Matrix and wedges.*

Fig. 4: *Initial result with all teeth restored.*

Fig. 5: *Restorations contoured and ready for polish.*

Fig. 6: *Polished case.*

Identifying the problem

First, we must accept that the adhesive/dentin interface is the weak link in the composite restoration.[1,3] The solubility and failure of the adhesive layer can be compounded by variables such as cavity prep design, improper etching, difficulty obtaining isolation, inadequate light energy, polymerization shrinkage, and the proliferation and varying properties of materials, which may result in gap formation. If oral fluids and bacteria penetrate crevices created between the tooth and the undermined composite restoration, it can lead to recurrent decay and premature failure.[1]

Next, we must understand that traditional composite restorations are passive and provide little chemical protection to the tooth. Historically, it was considered best practice to use passive restorative materials that did not interact with the oral environment and did no harm. However, this approach has been shown to lead to a higher susceptibility of composite restorations to secondary caries, because the passive materials allow for the accumulation of a high concentration of biofilm on the composite surfaces.[5,6]

Finally, we must look beyond the current generations of universal bonding agents, as Chen, Pashley, Tay, et al. did in their paper, "Bonding of Universal Adhesives to Dentin—Old Wine in New Bottles?" The article's conclusion states, "The increase in versatility of universal adhesives is not accompanied by technological advances for overcoming the challenges associated with the previous generations of adhesives. Therapeutic adhesives with bioprotective and biopromoting effects are still lacking in commercialized adhesives."[7]

Bioactivity and biomineralization

Bioactivity has been a buzzword in the dental industry over the past few years, and it's important to understand the meanings of "bioactivity" and "biomineralization," and how they apply to our practices.

The concept of bioactive materials was

introduced in 1969 and later defined as "one that elicits a specific biological response at the interface of the material which results in the formation of a bond between tissues and the material."[8] This definition has been developed further, and we now understand that a bioactive material is "one that forms a surface layer of an apatite-like material in the presence of [saliva or a saliva substitute]."[9]

Bioactive materials transport water and deliver minerals that are beneficial to tooth structure. They stimulate mineralization and the formation of chemical bonds that help to seal the tooth and prevent microleakage.[2] Bioactive materials are active, not passive, and play a dynamic role in the oral environment. They can reduce sensitivity,[10] can reduce marginal leakage and marginal caries[11] and can be less technique-sensitive.[12]

Nonpassive restorative materials have evolved over the decades, from glass ionomers to resin-modified glass ionomers (RMGIs), calcium silicates and a new class of aesthetic bioactive restorative composites. Glass ionomer cements (GIC) have enjoyed extensive use in dentistry, including in my practice, and are noted for a high level of fluoride release and recharge, along with the ability to form ionic bonds to tooth structure. The calcium aluminum fluorosilicate glass and polyacrylic acid mixture enables a chemical fusion and adhesion to tooth structure via transfer of ions contained in the glass. There are indications that there is a caries-preventive effect by the fluoride released from GIC materials at the tooth/oral fluids interface.[13] There is also empirical evidence of these anticaries properties, which have been noted by many practitioners (myself included).

Glass ionomers, however, do not meet the definition of bioactivity as it is understood today. In a study by Kim, et al., investigators tried to remineralize demineralized dentin by nucleation of new apatite crystallites within an apatite-free dentin matrix.[14] The study determined that GIC produced no apatite deposition in completely demineralized dentin samples that had been immersed in three types of remineralization media.

CASE 2

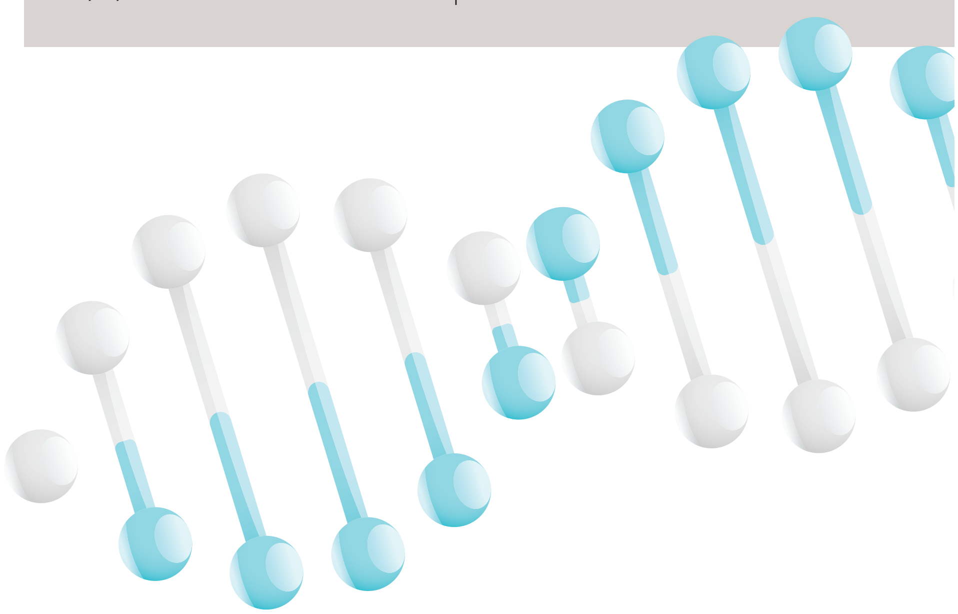
A 52-year-old patient presented with failing composite on #26. We see this often; it indicates microleakage at the material/tooth interface because of degradation of the bonding agent.

Fig. 7: *Preoperative image of failing composite on #26.*

Fig. 8: *After administration of anesthetic and placement of the Isolite isolation system, the tooth was wedged with a Diamond Wedge and prepared for restoration.*

Fig. 9: *VariStrip and wedge in place, and tooth restored with Activa Bioactive-Restorative composite.*

Fig. 10: *Final restoration after trimming and polishing.*



CASE 3

A 62-year-old patient presented for restoration of #30.

Fig. 11: *Preoperative image of failing composite on #30.*

Fig. 12: *Initial removal of failing composite reveals decay underneath.*

Fig. 13: *Placing a novel modified calcium phosphate bioactive liner material.*

Fig. 14: *Greater Curve matrix with Diamond Wedges, and restoration with Activa Bioactive-Restorative composite.*

Fig. 15: *Final polished restoration.*

Jefferies, et al., further illustrated that GICs do not form apatite. This study did, however, illustrate that two bioactive calcium-based materials, calcium aluminate and calcium silicate, stimulate apatite formation and could seal or reseal artificially created gaps in simulated aqueous physiological conditions. The clinical significance of these types of calcium containing bioactive materials is that they can improve the marginal stability of the tooth/restorative material interface and the long-term survival and serviceability of the restorations.[15]

Biomineralization is a process by which living organisms secrete inorganic materials in an organized manner.[16] Or, put another way, it's how the structure and properties of inorganic solids are deposited in biological systems. This occurs via the selective extraction and uptake of elements from the local environment and their incorporation into functional structures under strict biologic control.

The biomineralization process requires crystalline structures with specific ionic properties and of the appropriate size to organize and form biologic apatite. Essentially, if the proper building blocks are provided and water is present, remineralization can occur. Calcium and phosphate ions, along with water, are the essential components for this natural remineralization process.

Sauro and Pashley report the most recent research suggests amorphous (non-crystalline) calcium phosphate (ACP) enters collagen fibrils in a biomimetically stabilized "fluidic" state."[17] Research by Abuna, et al., illustrates that when demineralized dentin is covered with a flowable resin composite that contains ACP and is immersed in biomimetic polyanions, the calcium and phosphate ions can slowly diffuse through any water-filled porosities within adhesives and hybrid layers.[18] The investigators concluded that it would be possible to "backfill" such defects with apatite crystals and fossilize all dentin proteases as the matrix collagen remineralizes. This approach decreased nanoleakage and showed phosphate uptake and deposition of needlelike crystallites at the intrafibrillar level.

Discussion

How do we translate this science into clinical applications? Currently, there are several types of restorative materials for use in clinical dentistry that meet the criteria for bioactivity. They are dynamic materials that transport water and, in the presence of saliva, stimulate the formation of apatite at the restorative/tooth interface. To act as an amalgam and composite

CASE 4

A 54-year-old patient presented for replacement of failing amalgam on #12.

Fig. 16: *Preop image of failing amalgam on #12. Note the fractured mesial marginal ridge.*

Fig. 17: *Prepared tooth. Note calla lily-shaped cavosurface margins with no sharp angles. This enables a wraparound effect with the cured restorative material supported by tooth structure at the margins.*

Fig. 18: *Finished and polished Activa Bioactive-Restorative composite.*

Figs. 19a and Fig. 19b: *22-month postoperative evaluation, with two views of the restored #12.*

Fig. 20a and Fig. 20b: *38-month postoperative evaluation with two views of the restored tooth.*

Fig. 21: *49-month postop evaluation.*

Fig. 22: *53-month postop evaluation..*

replacement, however, the material must also have excellent aesthetics and durability and be insoluble in the moist oral environment; water cannot cause it to deteriorate. So, to be suitable for long-term clinical use as a definitive bioactive restorative material, the material must allow water to pass through it without compromising its physical properties.

I have been using Activa Bioactive-Restorative from Pulpdent in private practice for more than four years. As our confidence in the material increased, we have used it in almost every imaginable restorative situation and have never been disappointed. The case studies that accompany this article illustrate some common uses.

Conclusion

Hybridization and conventional composite restorations have been shown to have shorter durability than intended or desired. The preponderance of multiple generations of resin adhesives and the various additives proposed to overcome the challenges of resin-bonded adhesives lead to the conclusion that a change in methodology and direction is warranted. Strong, aesthetic, durable materials with bioactive or biomineralization capability will lead to an evolution in the dental restorative process. ■

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