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## A Review of Direct Restorations, Their Applications, and Possibilities

*Todd C. Snyder, DDS*

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# A Review of Direct Restorations, Their Applications, and Possibilities

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## ABSTRACT

Growing esthetic demands from patients and disproportional fear over mercury in amalgam fillings over the past 70 years has led to a significant increase in the use of composite resin for both anterior and posterior restorations. One of the best attributes of composite resins that practitioners could truly embrace was that they required little to no preparation, allowing for minimally invasive procedures that would preserve tooth structure and offer natural-looking results to their patients. This article will review the class of direct composite materials, including indications for their clinical application.

## LEARNING OBJECTIVES

- Review the history and evolution of tooth-colored direct restorative materials.
- Identify the characteristics of microfilled resins, hybrid composites, and nanofilled composites.
- Describe the appropriate clinical applications for each of the materials discussed.
- Discuss the future development possibilities for direct restoratives.

It has been said that, “you can never experience progress; you can only record it.” In relation to the dental profession and the materials that clinicians use on an almost-daily basis, it is quite interesting to reflect on how tooth-colored direct restoratives have changed since the initial silicate cements were first introduced in the United States in 1908. Since the introduction of adhesive bonding in the late 1950s and the emergence of modern composites and visible light-curing around 1978, substantial progress has occurred in dentists’ ability to place tooth-colored direct restorative materials and improve upon adhesion, durability, polymerization shrinkage, color, and microleakage.<sup>1</sup>

In 1947, tooth-colored direct restorations comprised of methyl methacrylate resins were introduced in the United States. Composite resins, developed by Bowen in 1962, marked a dramatic decrease in the use of silicate cements and acrylic resins. In fact, approximately 2 years after composite resins were introduced, the use of silicate cements and acrylic resins essentially came to an end.<sup>2</sup>

In the 1970s, the first acrylic resin replacement was introduced to the dental profession: composites.<sup>3</sup> The mixing problems that had plagued practices near and far seemed to become all but a memory as polymerization via electromagnetic radiation was brought into virtually every operatory. Unfortunately, this new material had its own issues: The particles were far too large, the resins were rather difficult to polish, and even though it presented patients with a much-desired tooth-colored restoration, only four shades were available. The acid-etch techniques also took their toll on remaining tooth structure, necessitating eventual endodontic therapy.

However, composite filling materials did provide new and exciting esthetic results the likes of which dentistry had never seen, but with the new materials came new challenges; less understood were incremental layering and material shrinkage.<sup>3</sup>

## MICROFILLED RESINS

Microfilled resins came into use in the late 1970s and early 1980s.



Filled with 35% to 50% pre-polymerized, 0.02- $\mu\text{m}$  to 0.04- $\mu\text{m}$  silicone-dioxide particles, microfilled composites demonstrated high polishability, stain resistance, and enamel-like translucency.<sup>2</sup> These restorations provided some of the lowest wear of any composite resin material to date. Indicated for restoring anterior teeth and cervical abfractions, microfilled composites still can rival any composite currently used for anterior esthetics. They are not, however, used in heavy stress-bearing restorations because they are prone to bulk fracture and marginal chipping.<sup>2</sup> Microfills do demonstrate high compressive strength and excellent wear characteristics. However, their higher thermal expansion coefficients, greater water sorption, polymerization shrinkage, and lower modules of elasticity, tensile strength, and fracture toughness made them less than ideal.<sup>2</sup>

### **COMPOMER COMPOSITES**

Compomer composites were introduced in the early 1990s as a hybrid combination of resin composite and glass-ionomer chemistry. Compomer contains poly-acid-modified monomers and fluoride-releasing silicate glasses. An acid-base reaction occurs as the compomer absorbs water after contact with saliva, which facilitates cross-linking structure and fluoride release. Just like a composite, compomers required a bonding agent and could release fluoride like a glass ionomer but could not recharge their fluoride ion content due to the resin component. Furthermore, the amount of fluoride they were able to release was only one-tenth of the amount released by glass ionomers. Compomers lacked the same strength and durability of composites or fluoride-releasing glass ionomers; hence, they were not used for long.<sup>4</sup>

### **HYBRID COMPOSITES**

Hybrid composites have a heterogeneous aggregate of filler particles that are typically filled with 70% to 80% by weight with 0.04- $\mu\text{m}$  and 1- $\mu\text{m}$  to 5- $\mu\text{m}$  filler particles. Hybrid composites typically have an average particle size of >

1-  $\mu\text{m}$ .<sup>2</sup> These composites demonstrate good handling characteristics and initial high polishability; however, they cannot maintain gloss due to the large particle conglomerates being plucked out of the resin matrix.<sup>2</sup> Therefore, manufacturers developed microhybrid composite resins with particle sizes reduced to 0.04  $\mu\text{m}$  to 1  $\mu\text{m}$ , making handling and polishing simpler.<sup>2</sup> The strength of hybrid composites allows for their use in both the posterior and anterior regions as a universal composite.<sup>2</sup>

### **NANOHYBRID COMPOSITES**

Today's nanohybrid composite resins produce highly esthetic, long-lasting restorations for many different indications.<sup>2</sup> Microleakage and fracture rate concerns have decreased significantly as the industry has gained greater understanding of advanced layering techniques, bulk-fill materials, low-stress materials, and modern self-curing chemistries.<sup>5</sup> In many cases, fewer shades of composites are necessary, with significantly improved chameleon effects offering exceptional esthetic outcomes, while enhanced filler particles promote excellent polishing, finishing, and longevity.<sup>5</sup>

Increasingly used for anterior and posterior restorations, composite resins have evolved considerably.<sup>6</sup> Modern nanohybrid composite resins demonstrate greater durability, better handling characteristics, less shrinkage, improved polishing, enhanced bond strengths, and highly esthetic outcomes.<sup>6,7</sup> However, composite placement remains technique-sensitive, and polymerization shrinkage and stress are still issues.<sup>6,7</sup>

### **NANOFILLED COMPOSITES**

Nanofilled composites, consisting of nanomers (5-nm to 75-nm particles) and nanocluster agglomerate fillers (0.6  $\mu\text{m}$  to 1.4  $\mu\text{m}$ ), are made up of zirconia/silica nanoparticles ranging from 5 nm to 20 nm in size.<sup>2,3</sup> A major positive esthetic feature of these materials is their outstanding



polishability and gloss retention.<sup>2,3</sup> Their makeup enables them to withstand a higher load, which allows the materials to be used in both the posterior and anterior. Because of the smaller particles' inability to reflect light, typically larger particles are added, improving the overall esthetics of the material.

## RESEARCH AND DEVELOPMENT EFFORTS

In more recent years, any modifications to composite resins have been to improve their physical and mechanical properties.<sup>1</sup> With a variety of shades, translucencies, effects, opacities, and innovative placement techniques, today's composites allow simple reproduction of the polychromatic and optical properties of the natural dentition.<sup>2</sup>

After more than 30 years of development, during which most manufacturers were concentrating on filler particle sizes and filler content by weight and volume, the research and development departments of some companies began looking at the chemistry of a tooth-colored direct restoration differently. In one example, GC America teamed up with DuPont to create a different chemistry for its resin composite backbone, offering a unique carbon chain that provided characteristics previously unseen. The production of G-aenial™ Universal Flow (GC America, [www.gcamerica.com](http://www.gcamerica.com)) marked the introduction of another new chemistry in dentistry.

Most dental composite manufacturers still concentrate on building their current traditional systems, addressing polymerization shrinkage by adding a bis-GMA/TEGDMA or bis-GMA/UEDMA/TEGDMA monomer combination to the organic matrix.<sup>3</sup> For dentin replacement, bulk-fill, low-shrinkage flowable composites were introduced as a result of heightened concerns over C-factor stress, which could induce microgaps and microleakage along the margins of the restoration–tooth complex.

Because shrinkage stress and the resulting leakage and sensitivity that can develop remain major concerns, many manufacturers continue to develop dental composites comprised of nanoparticles and larger agglomerates that demonstrate lower polymerization shrinkage.<sup>8</sup> Some additional products that manufacturers have been testing and are attempting to incorporate are spiroorthocarbonate, epoxy polyol, and siloxane-oxirane monomers.<sup>3</sup>

This new research led to such products as SureFil® SDR® flow (Dentsply Sirona, [www.dentsply.com](http://www.dentsply.com)), which was introduced in 2009. This innovative material used a “polymerization modulator” in the resin that reduced stress build-up upon polymerization without a reduction in the polymerization rate or conversion.<sup>9</sup> The polymerization modulator in the resin creates a more relaxed network and significantly lowers the polymerization stress compared to conventional resins. Furthermore, the unique resin chemistry allows for self-leveling and low stress for a dentin replacement flowable.<sup>9</sup>

A massive influx of bulk-fill flowable composites gave rise to concerns over depth of polymerization, shrinkage rates, and compressive strengths along with microbubbles and microleakage. Sonicfill™ (Kerr, [www.kerrdental.com](http://www.kerrdental.com)), because of its proprietary delivery device, became the first light-cured composite that integrated rheologic filler particles and ultrasonic technology. The rheologic filler particles allow the highly filled composite material to have its viscosity reduced by ultrasonic agitation, which is not possible with conventional particles. This allows the material to be better able to adapt in deeper, narrower preparation designs and require less adaptation compared to traditional composite chemistries. Many manufacturers followed suit, looking to create light-cured bulk-fill direct resins. Decreasing stress is one of the



main drawbacks of placing large quantities of resin as direct restorations; the other drawback is technique sensitivity with bonding to tooth structure. Having less stress on the bonding agent could allow for higher levels of successful long-term adhesion to tooth structure provided the bond to tooth is durable and long-lasting.

Long-term failure often occurs along the tooth margin and composite interface, typically in the deepest areas and proximal box, due to light-curing shrinkage stress and volumetric shrinkage. This problem has prompted a resurgence of traditional bulk-fill, self-cure materials. Thus, without visible light-curing of the direct composite resins, manufacturers can substantially decrease composite shrinkage and stress. Bulk EZ™ (Danville Materials, [www.danvillematerials.com](http://www.danvillematerials.com)) and Fill Up!™ (Coltene, [www.coltene.com](http://www.coltene.com)) are two examples of the many new similar resin technologies using dual-cure materials. Both of these products have the ability to be light-cured in addition to self-curing, although light-curing should not be performed until after the material has had adequate time to self-cure.

Self-curing chemistries offer significant reduction in C-factor stress but they still have polymerization shrinkage, which can create microtears or gaps if the technique and adhesion of the dentin bonding agent to the tooth is not strong enough to withstand the polymerization shrinkage. The development of dentin bonding agents has been another significant advancement. Many generations of such agents have existed since their introduction in the late 1950s.<sup>10</sup> Although markedly improved since their inception, bonding agents may not be the best material to interact with the tooth structure in the long term, due either to matrix metalloproteinases attacking the hybrid zone or their hydrophilic nature offering limited durability and declining mechanical properties.<sup>11-14</sup>

Thus, the conventional glass ionomers that have existed since 1968 and have undergone some chemistry modifications to allow them to be used as standalone, bulk-fill direct restorative materials with indications to fill restorations Classes I through V are another viable option to offer patients. The chief benefits of glass ionomers are that they are hydrophilic, they do not require a bonding agent, and they actually hypermineralize the dentin with which they come in contact.<sup>15</sup>

Self-cure, bulk-fill glass ionomers allow for decreased C-factor cusp deformation stress, polymerization shrinkage, and sensitivity while at the same time removing the need for a bonding agent.<sup>16,17</sup> There are many different brands of conventional glass ionomers on the market, and continued research and development is helping improve their physical properties. For example, continued development over the past 15 years has brought about many changes with the chemistry of the GC Fuji IX line of products (GC America). The most recent restorative to be introduced is the EQUIA® Forte (GC America), which can be used as a conventional bulk-fill glass ionomer with indications for use in Class I through V lesions as well as core buildups. Riva SC HV (SDI, [www.sdi.com](http://www.sdi.com)) is an example of a conventional glass ionomer that provides the benefits of chemically fusing to the tooth without the need for a bonding agent, along with remineralizing tooth structure and working well in a moist environment. Many other companies also have conventional and resin-modified glass-ionomer technologies. The main drawback has previously been in the areas of strength and esthetics.<sup>18,19</sup>

These glass ionomers have many valuable characteristics; not requiring a bonding agent and providing potentially less microleakage than a technique-sensitive resin chemistry in deep preparation designs is highly advantageous when restoring teeth.<sup>20-23</sup> More development in this area of technology and/or fusing this technology with



other materials could prove beneficial because of the glass ionomers' true adhesion to tooth structure, their ability to bond to moist dentin and provide fluoride release, and having a coefficient of thermal expansion similar to dentin. Additionally, they offer decreased gap formation and cusp deformation along with less technique sensitivity when compared with resin technologies.

Knowing how effective glass ionomers can be in helping to seal and restore a damaged tooth, many companies have incorporated some of the technology and characteristics into new types of products. Shofu ([www.shofu.com](http://www.shofu.com)), for example, has integrated glass-ionomer technology into its Beautifil® product line, in which a proprietary surface pre-reacted glass (S-PRG) filler particle is used within the resin matrix. This unique technology, which the manufacturer refers to as Giomer technology, releases six ions (fluoride, sodium, strontium, aluminum, silicate, and borate) into the tooth. This S-PRG filler particle has been shown to inhibit plaque formation and possess significant acid-neutralization capabilities.<sup>24</sup>

Another product merges the physical properties of a self-cured resin—strength, durability, esthetics, and polishability—with glass-ionomer technology to eliminate the need for a bonding agent while also offering the ability to remineralize a tooth. ACTIVA™ BioACTIVE-RESTORATIVE™ (Pulpdent, [www.pulpdent.com](http://www.pulpdent.com)) is a fusion of two different chemistries in one bioactive product that helps strengthen a tooth and fight off tooth decay and microleakage while still maintaining occlusion and withstanding occlusal forces. ACTIVA is the first bioactive composite with an ionic resin matrix, a shock-absorbing resin component, and bioactive fillers that mimic the physical and chemical properties of natural teeth without the addition of any bisphenol A (BPA), bis-GMA, and BPA derivatives. This highly esthetic

composite offers the benefits of glass ionomers in a strong, durable, resin matrix. Like glass ionomers, it chemically bonds to teeth, seals against bacterial microleakage, releases fluoride, is bioactive, and is more durable and fracture-resistant than most conventional composites. It releases and recharges with calcium, phosphate, and fluoride ions.<sup>25-33</sup>

Manufacturers have developed increasingly innovative products by combining many of the best characteristics in currently used materials. Dental composites are most often made up of an inorganic matrix, an organic matrix, and a coupling agent, as discussed earlier. Some companies have gone so far as to incorporate glass-ionomer technology into their resins for added benefits that traditional composites cannot offer.

Another unique new concept for restoring teeth has emerged. VOCO's ([www.voco.com](http://www.voco.com))Ormocer® (Organically Modified CERamics) technology, which was developed by the Fraunhofer Institute for Silicate Research and first used in 1999, has seen the incorporation of nanohybrid technology along with continued development of the Ormocer material, which has resulted in a new universal nanohybrid for direct restorations, Admira Fusion. Whereas most composites use a resin chemistry, this product uses silicon oxide as the main element making up the chemistry. Nanofillers, glass ceramics, and the resin matrix are all comprised of silicate technology and free of any traditional resin monomers (ie, bis-GMA, TEGDMA, HEMA). Currently, conventional resin composites have initial shrinkage rates of approximately 2% to 3%, but historically they have been as high as 5%. The Ormocer technology substantially reduces the amount of shrinkage by up to 50% with only 1.25% by volume. Additionally, the shrinkage stress is very low at only 3.87 MPa, which allows Admira Fusion to have very low shrinkage stress, minimizing the risk of C-factor

stresses. It also offers a high level of marginal integrity.<sup>34</sup>

## THE POTENTIAL FUTURE OF THESE MATERIALS

New tooth-colored direct restorative materials continue to improve upon traditional resin technology as glass-ionomer components are incorporated and even new types of materials altogether are created. Conventional glass ionomers will undoubtedly continue to evolve and perhaps incorporate other technologies to provide even better strength characteristics. Further levels of glass-ionomer technology may continue to be developed within current resin materials. Resin-free organically modified ceramic technology is an interesting category that is unique in the industry.

The path for future direct restorations is uncertain, but the profession can be sure that work will continue on the next big developments in tooth-colored direct materials.

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## A Review of Direct Restorations, Their Applications, and Possibilities

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- Microfilled resins came into use in the late 1970s and early 1980s; microfilled composites demonstrated:**
  - high polishability.
  - stain resistance.
  - enamel-like translucency.
  - All of the above
- Compomer composites were introduced in the early 1990s as a hybrid combination of:**
  - resin composite and glass-ionomer chemistry.
  - microfilled resins and silicate cement.
  - acrylic resins and silicate cement.
  - acid etching with fluoride release.
- Hybrid composites cannot maintain gloss due to:**
  - residual trapped acid from the etching process leaching to the composite surface.
  - the large particle conglomerates being plucked out of the resin matrix.
  - creation of an extra thick oxygen-inhibited layer after curing.
  - formation of a very thin oxygen-inhibited layer after curing.
- Nanofilled composites consist of:**
  - nanomers (5-nm to 75-nm particles) only.
  - silicone dioxide particles.
  - nanomers (5-nm to 75-nm particles) and nanocluster agglomerate fillers (0.6  $\mu\text{m}$  to 1.4  $\mu\text{m}$ ).
  - a heterogeneous aggregate of filler particles.
- Most dental composite manufacturers address polymerization shrinkage by adding a bis-GMA/TEGDMA or bis-GMA/UEDMA/TEGDMA monomer combination to the:**
  - inorganic matrix
  - organic matrix.
  - resin filler.
  - luting agent.
- The “polymerization modulator” in resin creates a more relaxed network and significantly does what compared to conventional resins?**
  - Increases polishability
  - Decreases polishability
  - Lowers the polymerization stress
  - Raises the polymerization stress
- Rheologic filler particles allow highly filled composite material to:**
  - darken one shade on polymerization.
  - lighten one shade on polymerization.
  - chemically break down to smaller particles during light-curing.
  - have its viscosity reduced by ultrasonic agitation.
- Self-curing chemistries offer significant reduction in C-factor stress but:**
  - they are very expensive.
  - they still have polymerization shrinkage.
  - there is a dramatic increase in postoperative sensitivity.
  - they require the temperature to remain constant while curing.
- Self-cure, bulk-fill glass ionomers allow for decreased C-factor cusp deformation stress, polymerization shrinkage, and sensitivity while at the same time:**
  - removing the need for a bonding agent.
  - releasing sodium fluoride.
  - releasing calcium fluoride.
  - releasing strontium fluoride.
- Glass ionomers have a coefficient of thermal expansion:**
  - similar to dentin.
  - similar to enamel.
  - much greater than enamel.
  - much less than dentin.

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