Composite Resins Revisited

by Karl F. Leinfelder, DDS, MS & Douglas Terry, DDS

Educational objectives

Upon completion of this course, participants should be able to achieve the following:

• Better understanding of the variables that control restoration durability.
• Understand pertinent information related to the use of flowable composite resins.
• Generate a better understanding of the principles involved in the finishing and polishing of composite resin restorations.
• Relate occlusion to clinical longevity.

Throughout the last two decades an overwhelming number of new restorative materials and techniques have been introduced to the dental profession. Undoubtedly, this all came about with the development of composite resin by Raphael Bowen in the early 1960s, as well as the ability to bond to tooth structures – first by Hagger and then by Michael Buonocore. The ability to generate clinically acceptable bond strengths to dentin by Nobuo Nakabayashi further accelerated this process. Today, the combination of highly wear resistant composite resins and the ability to bond to dentin has led to the potential for total replacement of amalgam with a more aesthetic material. It also has led to the use of considerably smaller cavity preparations and a minimal need for mechanical retention thereby increasing the potential for a greater longevity of the restoration.
It is also interesting to note that bonded restorations have virtually eliminated the need for retentive pins. Prior to the advent of adhesion to enamel and dentinal surfaces, a wide variety of pins had been promoted for use in conjunction with the retention of anterior resin restorations. Threaded or cemented pins were commonly recommended for patients who presented themselves with gross incisal fractures. Soon thereafter pin retained amalgams gave way to bonded composite resin restorations.

The first clinical use of posterior composite resin came about in 1970. Typical example included Addent (3M Co.) and Adaptic (J&J). Based upon the results of a one-year clinical study at the University of Indiana, composite resins were recommended as a replacement for amalgam in Class I and II cavity preparations. Using the United States Public Health Service criteria (Ryge), the amount of occlusal wear of the composite resin restorations were found to be at least as good as those of the amalgam controls. Furthermore, the composite resin restorations showed less ditching along the margins as compared to their amalgam counterpart. After the second and third year of evaluation however, the wear of the composite resin restorations was shown to be considerably greater than the amalgam controls. On this basis, it was recommended that the use of composite resin in posterior teeth be abandoned. Such results were confirmed in other clinical investigations.

Continuous studies at both the manufacturing and academic level resulted in the development of composite resins that were appreciably more resistant to wear. The original composite resin formulations exhibited wear rates as high as 50 to 100 microns per year. By the mid 1970s the wear rate was decreased to around 25 microns. Finally, by 2000, the annual wear rate was reduced to equal that of amalgam or about five microns annually. The improvements came about through a number of factors. However, the most significant of these included a substantial reduction in the particle size as well as increasing the filler/matrix ratio. Reducing the size of the particle fortuitously increased the polishability of the restorative surface.

**Packable Composites**

A major change in the resin viscosity came about in 1998 with the first introduction of the so-called “packable” composite resin. It was the intent of various manufacturers such as Pentron Clinical Technologies, who developed ALERT, and Dentsply/Caulk, who generated Surefil, to impart handling characteristic similar to that of a freshly triturated mass of amalgam. The concept was introduced to help the clinician switch over from amalgam to composite resins. It was believed that if the composite resin exhibited all or most of all the handling characteristics of amalgam (including condensation) the clinician would more readily accept the new material. The introduction of these new materials did convince an appreciable number of general practitioners to make the change.

The term “packable” comes from the fact that low viscosity resins take considerable effort to force the restorative agent into the details of the cavity preparation. Illustrated in Fig. 1 is a portion of the packable composite resin after extrusion from the syringe. The indentations on the surface of the extruded material were generated by impressing it with an amalgam plunger. Regardless of how long the composite rests undisturbed upon the table top it will not flow or change dimensions under its own load.
It should be pointed out that some practitioners refer to the new composite resins as condensable. In essence they are not condensable. Rather they are packable. Condensation refers to a condition by which the fillers are compressed closer together and correspondingly causes an extrusion of the resin matrix component. Amalgam is appropriately identified as condensable since the alloy particles are forced together while causing the extrusion of the free mercury.

Another interesting characteristic of the packable composite resin is that they generally do not stick to the surface of the placing instrument. If the resin does adhere to the instrument, there might be a tendency for microscopically separating the material from the wall of the preparation. This in turn could contribute to secondary caries and/or marginal discoloration.

The Universal Composite Resins:
The term universal refers to the fact that the composite resin can be used equally as well in anterior teeth as well as posterior teeth. Such a concept implies that the formulation is highly aesthetic and wear resistant. At the present time most of the manufacturers of dental restorative materials offer excellent choices. In addition to an excellent range of available shades, the universal composite resins commonly can be polymerized to a depth of approximately 4mm.

The first universal composite resin to appear on the market was Esthet-X and was developed and marketed by Dentsply/Caulk. For the sake of convenience the resin is packaged in syringes as well as in compules.

One unusual feature to the Esthet-X system is the shade guide. Instead of selecting only one shade, multiple shades are recommended when the restoration is large or extensive, such as in the case of facial veneers or incisal fractures. Illustrated is the reverse side of the shade guide (Fig. 2). Note that for each shade selected, there are three shades indicated. The first is the opaque, followed by the regular or body shade and finally the translucent shade. In the case of a fractured central for example, 65 percent of the body of the restoration is built up with the opaque shade. The last one third of the restoration then is constructed from the regular or body shade. The entire surface is covered with the translucent shade. Such a technique generates a three dimensional highly esthetic restoration.

The next universal composite resin to be introduced was Filtek Supreme with nanofiller loading. Manufactured and marketed by 3M ESPE, this composite resin is characterized by excellent esthetic properties. Part of the esthetic properties can be attributed to the fact that the resin contains nanofillers.

In essence there are two types of nanofillers. The first one (Type I) is generated by building up the particle from an elemental or atomic level. Conventional filler particles are generated by continuous grinding of larger particles into small particles. The grinding process unfortunately is limited to dimension. Specifically, the smallest size that can be produced generally is about 0.5 microns. The process is a lengthy one and may require up to three days of continuous ball milling or grinding.

The second type (Type II) is also a building up process rather than a grinding down process. However the ultra small nanoparticle consists of a cage-like structure consisting of eight silicon and 12 oxygen atoms. Most composites containing nanofillers usually consist of Type I. Supreme (3M ESPE) is an example. Pentron’s nanofiller composite materials (Simile and Artiste) consist of Type II. Rather than serving as an additive particle to the resin it actually is bonded
to the resin matrix. The reactive groups can vary for the purpose of modifying specific properties of the composite material. Examples of the reactive groups are alcohols, phenols, amines and esters as well as a large number of other groups. Some of the properties that can be modified with the POSS nanoparticle include the following: hardness, creep, compressive strength, toughness, viscosity and polishability.

One of the most recent universal composite resin available to the profession is Artiste. This system is notable for its outstanding ability to mimic tooth structure while attaining excellent surface texture. The Artiste system is available in two sets of color matching abilities: one is enamel and the other is dentin. Furthermore, this nanofilled composite resin is available in either single does or in a syringe.

Another highly aesthetic universal composite resin is Venus, manufactured and marketed by Heraeus. Available in syringes as well as single doses, Venus is distinguished by its handling properties as well as its aesthetics in both anterior and posterior teeth.

Illustrated in Fig. 3 is the specific shade guide to be used in conjunction with Venus. In contrast to most composite resins the shade tabs are actually made of composite resin (Venus) rather than poly methylmethacrylate. The purpose is to generate a restoration that is exactly the same as the shade guide itself. Procedurally, after selecting the appropriate shade, the guide is reversed for proper selection of the enamel and body (dentin shade). Based upon a principal similar to the Dentsply/Caulk shade guide, this one is a bit simpler. For a small and inconspicuous restoration the enamel shade is selected. For a more complex restoration such as a fractured central, the dentin and enamel shades are chosen.

Flowables

The flowable composite resin liner highly wets the surface of the preparation far better than the composite resin formulation. The difference in wetting abilities is illustrated in Fig. 4. Note that the contact angle associated with the flowable is far less than it is with a composite resin. The low contact angle (degree of wetting) associated with the flowable composite resins is an indication of how well it will wet and relate to all of the irregularities in the cavity preparation.

When using the flowable composite resin it is important to cover all the dentin. If after placing the flowable agent one can visualize any surfaces of the dentin, the placement is incomplete. The flowable composite resin liner should cover even the dentin in the gingival box of the preparation. If wedging of the matrix band brings it into tight contact with the gingival margin, it is permissible to bring the flowable agent up to the matrix band itself. If any space exists between the matrix band and the gingival margin there is then the potential for allowing the flowable to seep beyond the gingival margin, thereby creating an overhang. Such abnormalities might be difficult to remove.

Furthermore, the thickness of the flowable resin should range between 0.5 and one micron. It is acceptable for the flowable composite resin to be greater than 1mm. However, it is important not to cover the occlusal margins or establish the proximal surface with the flowable agent. Flowable composite resin along the occlusal margins will wear away faster than the composite resin with which it is used.

Fig. 3 Shade guide (Heraeus Kulzer)

Fig. 4 Contact angels associated with universal and flowable composite resins.
It should be remembered that as compared to conventional posterior composite resins the flowable resin is comparatively inferior. Some of the inferior characteristics include the following:

a. Curing shrinkage: while most composite resins exhibit a curing shrinkage of up to three percent that associated with the flowable agents may be twice that amount. The reason for the elevated polymerization shrinkage of course, relates to the fact that flowables commonly contain more diluents than conventional composites. They also contain less filler particles.

b. Water sorption: greater for the flowable composites

c. Compressive strength: less than conventional composites

d. Elastic modulus: as much as one half that of conventional composites

e. Wear resistance: appreciably less than composites

The flowable composite resin has two functions. The first of these includes the development of an intimate relationship between the walls of the cavity preparation and the surfaces of the flowable resin (prevents gap formation). The second serves as a stretchable liner to absorb the shrinkage or contraction of the overlying composite resin restoration.

There are three specific properties that should be considered before purchasing a flowable composite resin. The first of these is handling characteristics. The second is radiopacity and the third is cost, which may range anywhere from $5 to $14/gram. Radiopacity may be the most important of these. Unless the radiopacity is sufficiently high, incorrect radiographic interpretations can be made. The ADA has developed a simple standard for ready use. The standard consists of comparing the radiopacity of a given material against the radiopacity obtained from a one millimeter thick slab of aluminum. The opacity of a given resin then is described as the relative opacity as compared to the standard in percent. A radiopacity of 400 percent, for example, would then be four times greater than the aluminum standard used by the American Dental Association.

**Pre-cure Burnishing Technique**

a. Reduces considerably the post-cure finishing time when the composite resin is burnished in the pre-cure state, the time to properly finish the surface takes only a couple of minutes at the most. The reason of course is that little composite resin has been extended beyond the occlusal margins.

b. Takes 5-10 seconds: Removal of the non polymerized composite resin can be very fast, particularly in comparison to removing it after curing.

c. Optimizes wear resistance: The problem with surface reduction using a multi-bladed carbide instrument or fine diamonds is that they may possibly cause the creation of small cracks on the composite resin surface. This in turn then can readily lead to a weakened surface which in turn is less resistant to wear.

d. Assures marginal integrity.

Pre-cure burnishing technique

Removes residual material and optimizes the margins: composites were originally inserted into the cavity preparation much the same as amalgam. Specifically the preparation was filled well beyond the occlusal margin up to the midpoint of the incline planes. Now after curing with the light, all the excess material had to be removed. Such a process was exceedingly time consuming. Furthermore since the color of the composite resin as well as the ground upon surface texture closely resembled that of enamel, the true margin or interface was difficult to define. A careful examination of numerous replicas of surfaces finished in that manner revealed that the clinician overcut the composite past the occlusal margin by about 25 microns. Since the wear of composite resins currently approximates only five microns, the amount lost at baseline can be considered as excessive.

The composite resin used by the clinician today represents the accumulation of years of research and clinical testing. The products of tomorrow promise to be even more exciting.
References

Authors’ Bios
Karl F. Leinfelder, DDS, MS, a native of Wisconsin, earned both his Doctor of Dental Surgery and Master of Science (Dental Materials) degrees from Marquette University. After serving for eight years on the faculty at Marquette, he joined the faculty at the University of North Carolina School of Dentistry where he attained the rank of Professor and Director of Biomaterials Clinical Research in the Dental Research Center. In 1983, he joined the School of Dentistry at the University of Alabama and is the recipient of the Joseph Volker Chair. He also served as Chairman of the Department of Biomaterials until 1994. Presently he holds positions at both universities; adjunct professor at University of North Carolina and Professor Emeritus at the University of Alabama. Dr. Leinfelder has published nearly 250 papers on restorative materials, authored more than 150 scientific presentations, a textbook on restorative materials and techniques and has lectured nationally and internationally on clinical biomaterials.

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1. Another name of packable composite resins is which of the following?
   a. Hybrid
   b. Low viscosity
   c. Condensable
   d. Microfilled
   e. Macrofilled

2. The first clinical use of posterior composite resins occurred at about which year?
   a. 1960
   b. 1970
   c. 1980
   d. 1990

3. Universal composites are designed for use in which of the following situations?
   a. Direct filled posterior teeth only
   b. Anterior and posterior preparations
   c. Porcelain substitute
   d. Indirect restorations
   e. Abfraught lesions

4. The depth of polymerization for most of the universal composite resins is about how many millimeters?
   a. 1.0
   b. 2.0
   c. 3.0
   d. 4.0
   e. 8.0

5. Nanofillers are generated by which of the following techniques?
   a. Short term grinding
   b. Long term grinding
   c. Building from the elemental state
   d. Quenching in cold water
   e. Fusion

6. Contact angles can be used to predict which of the following?
   a. Wettability
   b. Strength
   c. Hardness
   d. Elasticity
   e. Ductility

7. Flowable composites exhibit several characteristics that are inferior to conventional composite resins. These include which of the following?
   a. Polishability
   b. Elastic modulus
   c. Color matching characteristics
   d. Wettability
   e. Curing time

8. Failure to use a flowable composite may result in which of the following?
   a. Fracture of the restoration
   b. Gap formation at the margins
   c. Reduced wear resistance
   d. Poor color matching ability
   e. Increased water absorption

9. The following properties should be considered prior to selecting a flowable composite resin restorative material:
   a. Color
   b. Radiopacity
   c. Surface texture
   d. Curing light
   e. Internal porosity

10. Pre-cure burnishing of the occlusal surface of the restoration is carried out for which of the following reasons?
    a. Enhance color matching
    b. Elimination of postoperative sensitivity
    c. Reduce post-cure finishing (grinding) time
    d. Condense the filler particles closer together
    e. Prevent filler particles from falling out
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