Composite resins were introduced to the dental profession in the 1960s. They represented a major improvement in the aesthetic restorative systems that preceded them. Silicate cements and acrylic resins, for example, fell short of what is considered ideal restorative materials. Silicate cement restorations normally exhibited a clinical longevity of only three to five years. Furthermore, they could be used only in non-stress-bearing areas. Acrylic resins were characterized by discoloration, leakage, and secondary caries. The composite resin, although considerably short of being ideal, did demonstrate good potential. With some improvement in the mechanical characteristics, composites were recommended as a posterior restorative material. Unfortunately, however, clinical studies revealed that composite resins could not be used as a posterior restorative agent. Problems of wear under occlusal loading and secondary caries particularly in posterior teeth were prevalent.

Developed by Dr. Raphael Bowen in the 1960s, composite resins have been subjected to a great deal of research by manufacturers and universities. While there were many contributing factors to a less-than-acceptable performance, the single most important variable was the filler particle. The average early particle size ranged between 25 and 50 microns. Today the average particle size is only 1 micron. Ultra-small filler particles have successfully resulted in excellent wear-resistance, polishability and handling characteristics. Perhaps the most impressive property improvement was the resistance to wear. As shown in figure 1, the wear rate of composites decreased from 50 to 100 microns per year (thirty years ago) to the present 5 microns. This means that the average annual wear rate is the same as amalgam. These wear rate values are in excess of the surrounding enamel into which they are placed.

Packable or Universal Composite Resins

One of the most recent changes in composite resins came about with the introduction of a very viscous formulation. Commonly referred to as a universal composite, the filler content has been increased appreciably. Also identified as a packable composite, the material can be used equally as well in anterior and posterior teeth. Along with the introduction of a more viscous and packable composite some manufacturers offer a dentin shade. For the ultimate in aesthetics the dentin and enamel shades are recommended. The larger the preparation the greater the need for both shading systems, particularly in anterior teeth. Standard cavity preparations commonly need only one shade. As a rule, shades A2 or A3 will provide excellent aesthetics (posterior teeth) and can be accomplished with just the enamel formulation.

The advantages of using the packable composites are multiple. The high viscosity composites can be manipulated so as to generate the desired anatomic form with the appropriate hand instrument. After light curing the amount of composite resin removal of the excess composite is relatively minimal. In addition to the sculptibility of the heavily loaded resin, the depth of cure has been improved. Some of the formulations in fact can be cured to a depth of 4-5 mm. This might be a double-bladed sword since such formulations tend to be more sensitive to ambient light. This then means that the clinician should manipulate the composite without the use of the operating lamp. One can also use an appropriate light filter instead.

Another interesting property of the packable composite resins is that they are generally non-sticky. If the composite resin possesses this undesirable characteristic it will adhere to the surface of the plastic-placing instrument. Should this happen, it is possible that the resin will be partially pulled from the preparation; thereby leaving a microscopic gap at the resin-preparation interface.

Fig. 1: Wear Vs. Time

![Figure 1: Wear Vs. Time](image)


**Composites**

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face. Such a condition could lead to microleakage and discoloration along the margins. Finally the composite resin belonging to this class of resins is highly wear-resistant. This means that if the operator so desires, he or she can substitute it for amalgam under most conditions. It should be remembered that the larger the composite resin restoration, the shorter its longevity.

The introduction of the universal composite resins was accompanied by a new type of filler. Identified as nanofiller this particle is very different than conventional fillers. The latter are generated by long-term grinding of larger particles into smaller ones. The process might take a number of days to complete and is commonly limited to about 1 micron in dimension. In the case of the nanofillers, the particles are built up from the elemental level to the desired size. Interestingly there is another type of nanofiller. This one has a cage-like structure consisting of eight silicon atoms and 12 oxygen atoms. The cage-like structure, which actually bonds to the composite resin molecule, possesses a reactive sight to which various other compounds can be added. These molecular structures are added for the purpose of modifying the composite resin. Such add-on groups might consist of alcohols, phenols, amines and esters to name a few. Some of the properties that can be modified by the incorporation of the nanofiller into the resin matrix include: improved hardness, polishability, impact toughness, viscosity, packability, compressive strength and reduction of creep.

The New Shade Guide

At least two different manufacturers (Dentsply/Caulk, Heraeus Kulzer) have marketed a modified guide (Fig. 2a,b) for determining the appropriate shade. While the conventional shade guide contains only one shade for each shade tab, the newer systems mentioned above contain two or three shades to select from. For example, for each shade on the guide there is a dentin shade and an enamel shade. The dentin shade correlates to the body composite (dentin) whereas the enamel shade relates to the enamel. On one of the shade guides (Dentsply/Caulk) there is also a selection for the enamel glaze if so desired. Again, the greater the dimension of the restoration, the greater is the need for using dentin and enamel.

Composite Resin Insertion

Currently there are numerous recommendations for the insertion of a posterior composite resin. Some recommend segmental (numerous) insertion of the composite while others suggest larger portions. The numerous insertions (each followed by curing with the light) technique is said to reduce the pull of the composite resin away from the wall of the preparation during the curing process.

The following technique is offered which is based upon a greater size of the individual segment: After the preparation is etched and hybridized (application of the dentin bonding agent) the flowable liner is placed. In essence there are three rules as it relates to the flowable liner. The composite resin liner should be approximately 1 mm thick. Secondly it should cover all the dentin. In other words it should cover all the walls of the preparation up to the dentino-enamel junction. And thirdly it is important not to place the liner in areas such as the occlusal surface or the proximal surface. The reason for this is that the liner material is less resistant to wear than the overlying composite resin. Incidentally, it is permissible to have the liner thicker than 1 mm if so desired but never less than 0.5 mm. It should be remembered that the flowable composite resins are appreciably inferior to conventional composites. They, for example, exhibit a higher polymerization value than conventional composites. Furthermore they have a higher absorption rate for water, lower compressive strength and a lower modulus of elasticity. Finally, as already mentioned, the flowable composites are less wear-resistant. A comparison of the wear resistance of the flowable and conventional composites is presented in figure 3.

Flowable composite resins have two very important functions. The first and most obvious is that they intimately wet all the surfaces of the cavity preparation. The one problem of the universal or packable composite resins is that they do a relatively
poor job of wetting the surfaces to which they are applied. Their wetting potential can be compared to a section of concrete poured into a matrix. Unless special techniques are employed the surfaces poured against the matrix will be filled with porosity (Fig. 4). Under clinical conditions the porosity associated with the composite resin could give rise to post-operative sensitivity.

The second reason for using a flowable composite resin is that the use of high-intensity lights tends to cause the polymerization shrinkage to occur near the margins of the restoration. More homogenous shrinkage throughout the composite occurs when a low-intensity light is employed. This is the reason that “ramp-curing” is recommended by a number of authors.

Flowable composite resins or liners are widely used by the dental profession. They are important for a couple of reasons. First of all they generate the potential for achieving excellent marginal adaptation. Secondly, they also provide assurance against polymerization contraction of the overlying composite resin which could pull the composite away from the walls of the preparation. While it is important to note that this auxiliary material is used widely by the profession, it is appropriate to determine what parameters are essential when considering the acquisition of a composite resin liner. The first of these relates to handling characteristics. Does the material flow freely over the dentinal surface when instrumented with an appropriate instrument such as a Dycal applicator (Dentsply/Caulk)?

The second is radiopacity. The American Dental Association (ADA) has developed a standard against which all resin systems can be measured. Consisting of an aluminum bar 1mm thick, a radiograph is made for the purposes of comparison with any resinous system. Degree of radiopacity relates to a comparison of the standard with a material being considered. Relative difference is measured in percent. Ideally the material being considered should be as great in opacity as the ADA standard or even greater. Some materials on the market are as much 400 percent greater than the standard. Figure 5 illustrates the differences amongst several materials in terms of radiopacity. The last consideration in the acquisition of a suitable flowable composite resin liner is cost. Presently one of the least expensive flowable is Flow-IT (Pentron Clinical Technologies). Surprisingly there is a major difference in costs amongst the various materials per millimeter. According to The Dental Advisor the amounts range from $8.45 to $37.45.

Recently a new flowable composite resin was released to the profession identified as Fusio (Pentron Clinical Technologies); this is a self-adhesive resin liner or flowable composite resin. Some of the outstanding properties of the material include the following: self-adhesive, seals dentin, no etching of the preparation, no bonding agent, radiopaque and high bond strengths. Procedurally the preparation is rinsed and slightly air dried. Fusio is then applied to the dentin with a swabbing motion. After 15 seconds the liner is photo-cured for 15 seconds. This then is followed by the application of the composite resin. In essence the material is applied with a microbrush and then light cured. It is also possible to use Fusio as a dentin replacement. In this case the self-adhesive liner is laid down all the way to the dentino-enamel junction in such a way that the removed dentin is completely replaced by Fusio. Procedurally this is accomplished by filling in with 2mm segments; curing each segment for 15 seconds with the light-curing unit.

**Composite Resin Insertion**

The clinician has two choices for insertion of the composite resin into the preparation. Either the material is segmentally inserted or it is bulk filled. It is interesting to note that while most clinicians segmentally fill the preparation, a study at the University of Minnesota has sanctioned bulk filling as an accept-
able procedure. The following technique describes a procedure that is intermediate between the two.

After hybridizing and placement of the composite resin liner, composite resin is inserted into the preparation. Depending upon the size of the preparation the material is bulk filled or segmentally filled. In a standard cavity preparation where the floor of the preparation is only 2mm deep the operator can use a bulk-fill technique. If the floor of the preparation is 4-5mm below the margin the preparation can be filled with only two segments. In the case of the 4-5mm deep preparation the first segment is inserted. This layer is light-cured for 15 seconds. Next the second segment is inserted. Care is taken to fill the preparation only to the cavosurface angle. Do not cure the composite.

Using a burnisher such as the PKT 3A, any excess composite extending beyond the margin is removed. Procedurally, the instrument is held between the thumb and two forefingers. Under pressure the instrument is moved along the margins. Such a technique removes any excess composite while filling in areas where there is a deficit. Using the same burnisher the clinician can establish the central fissure, lingual and buccal developmental grooves and finally the incline planes. At this point, the composite is light-cured for 20 seconds. A check of the occlusion with articulating paper will surprisingly reveal little excess to remove. This technique considerably minimizes the amount of post-cure surface grinding and finishing.

If the composite is overfilled and then cured as is commonly done, the operator spends unnecessary time removing excess material. It should be pointed out that it is somewhat difficult to find the exact margins without removing some of the occlusal enamel in the process. An examination of replicas made of restorations done in this manner reveals that the operators commonly removed nearly 25microns of composite below the enamel margin (University of North Carolina). Furthermore, the preparation sometimes occurs, particularly on the occlusal surface. There is a number of factors that lead to this problem. The first of these is related to the presence of a thickened layer of the dentin bonding agent. Such a problem is generated by failure to adequately air disperse the bonding agent prior to application of the light (curing). The line is visible because the refractive index is different than both the composite resin restoration as well as the surrounding enamel. Such a condition might be aesthetically objectionable but not necessarily a problem in terms of clinical longevity. The white line might also be caused by a fracture in the enamel along the margins of the preparation (Fig. 6).

White Lines

White lines at the junction of the composite and the margin of the preparation sometimes occurs, particularly on the occlusal surface. There are a number of factors that lead to this problem. The first of these is related to the presence of a thickened layer of the dentin bonding agent. Such a problem is generated by failure to adequately air disperse the bonding agent prior to application of the light (curing). The line is visible because the refractive index is different than both the composite resin restoration as well as the surrounding enamel. Such a condition might be aesthetically objectionable but not necessarily a problem in terms of clinical longevity. The white line might also be caused by a fracture in the enamel along the margins of the preparation (Fig. 6). Normally this line will occur parallel to the margin and about 1-2mm away from the restoration-tooth interface. While the white line associated with excess dentin bonding agent might not be a clinical problem that associated with a fracture should be dealt with. The fracture line can easily be treated by first acid-etching the area, washing and drying for a couple of seconds. At this point a dentin bonding agent is applied. Such a technique bonds together the enamel on both sides of the crack.

White lines can be caused also by rapid curing of the restoration particularly when no flowable agent is used. The cause is related to the fact that rapid curing, high-intensity lights cause the composite resin to shrink along the margins rather than homogenously. Another possible candidate for white lines might happen when the preparation is wide buccal-lingually but shallow in a pulpal direction. Under such a condition the composite tends to shrink more two-dimensionally rather than three-dimensionally. Finally, white lines might occur when the occlusal enamel isn’t supported by sufficient dentin. The lateral pulling on the enamel when insufficiently supported by dentin can cause the enamel to fracture. Again such a condition can be treated by etching, followed by bonding.

Finishing and Polishing

Immediately after light-curing the occlusal component of the restoration is surfaced with a 12-bladed carbide bur. If the burnishing is done properly, there will be relatively little composite to modify with the finishing instrument. When the anatomy is established the final surface can be done with the finishing bur using light pressure and a slower speed. The proximal margins can then be addressed with a Bard Parker 12B. Sliding the instrument along the margins the blade removes overhangs and extended composite resin in a easy way. Sof-flex discs (3M ESPE) are also excellent for dealing with the proximal margins. Next the surface can be polished using either the PoGo system (Dentsply/Caulk) or Enhance polishing cups and Prisma polishing pastes (Dentsply/Caulk).

Author’s Bio

Dr. Karl F. Leinfelder earned both his Doctor of Dental Surgery and Master of Science (dental materials) degrees from Marquette University. 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 two universities; adjunct professor at University of North Carolina and Professor Emeritus at the University of Alabama. Dr. Leinfelder has published more than 275 papers on restorative materials, authored more than 150 scientific presentations, two textbooks on restorative systems and has lectured nationally and internationally on clinical biomaterials.