

IMPROVING THE POLYMERIZATION OF COMPOSITE RESINS

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During the last several years, the viscosity of many composite resins has increased considerably. This change was designed to generate a consistency similar to a freshly triturated mass of amalgam to increase strength and reduce shrinkage and for the conversion of amalgam-only users. Further, a substantial increase in viscosity would provide the clinician with a means for establishing a proper anatomic form prior to curing, which would result in a considerable reduction in the amount of effort required to finalize the surfaces of the restoration after polymerization.¹

While the dental community has generally responded positively to this modification, the elevated viscosity has contributed to a related clinical problem. Specifically, these restorative systems do not wet or adapt to the walls of the preparation as did their predecessors. Unless special procedures are followed, the incidence of porosity at the preparation-restoration interface can be substantial, which can ultimately result in postoperative sensitivity.^{2,3}

Another factor associated with lack of excellent margin integrity relates to the involved curing light.^{4,5} Over the last several years, the intensity of both high-energy quartz halogen units and LED systems has increased from less than 500 mW/cm² to more than 1,000 mW/cm².⁶ It is now a well-established fact that the greater the intensity of the curing lamp, the greater the concentration of the contraction forces at the margin of the restoration.⁷ As a result, the curing composite material tends to pull away from the margin, leading to inferior margin integrity.

In an attempt to resolve this limitation, flowable composite resins were introduced.⁸ These modified resins retain the same particle size as conventional composite resins, but in decreasing numbers. There is also the possibility that the level of diluents (TEDGMA) may have been increased to further enhance fluidity. While decreasing the filler level reduces viscosity, it also affects numerous other physical characteristics (eg, wear resistance, compressive strength, diametral tensile strength, flexural strength, modulus of elasticity and toughness).^{9,10} As a result, flowable resins generally cannot be recommended for use as a restorative material in high-stress-bearing regions, unless the preparation is considerably smaller in dimension than that which is normally encountered. Furthermore, they should not be used in the proximal contact regions of posterior teeth.

The reduction in the elastic modulus (approximately 35% of conventional composites), however, can be used to the clinician's advantage.⁸ When placed as a liner on the dentin surfaces of the cavity preparation, the overlying composite resin tends to pull away from it during polymerization. The greater the intensity of the light and the greater the bulk of material being cured, the greater the tensile stress.

Due to its reduced modulus, the flowable resin material tends to strain more than the overlying composite resin. This property of the flowable resin tends to impart a cushion effect against the shrinking composite, thereby reducing the potential for stress release and enhanced



Figure 1. Preoperative occlusal view of interproximal decay on teeth #18(37) and #19(36).



Figure 2. Removal of decay with minimal slot preparations.

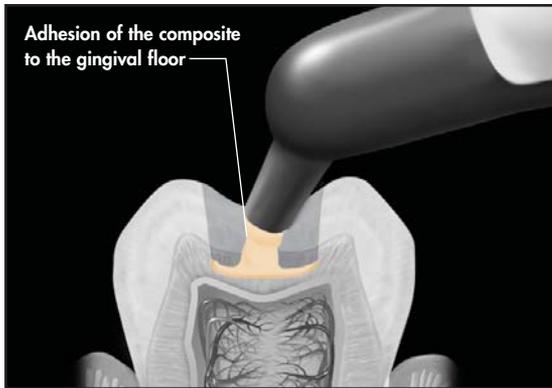


Figure 3. An illustration of the composite heating device (ie, Calset, AdDent Inc, Danbury, CT) and projected improvement in level of polymerization.



Figure 4. Heated hybrid composite flowed onto the gingival floor with adaptation to floor and sectional matrix to provide a proper marginal seal.



Figure 5. Final layer of the same composite resin material used to complete the restoration.



Figure 6. Postoperative occlusal view of the definitive restorations following the completion of finishing and polishing.

marginal integrity. In essence, the flowable composite resin liner enhances surface adaptation through wetting and prevents interfacial separation at the margins.

Polymerization Versus Temperature

The conversion of double-bonded carbon groups to single bonds during the polymerization is far from complete, regardless of the curing method used. In fact, the level of conversion is commonly less than 65% and is sometimes less than 50%.^{11,12} The conversion is commonly influenced by the monomer, filler, and the light-curing procedures. The reason can be related to an increase in the viscosity of the growing polymeric chain which prevents the initiator from coming into contact with the carbon groups. As the level of unreacted or residual monomer increases (ie, the degree of conversion), the mechanical characteristics (eg, modulus of elasticity, flexural strength, resistance to wear) of the finalized restoration decreases.

Elevating the temperature of the composite resin prior to its insertion into the cavity preparation has a positive influence on the level of monomer conversion and this,

therefore, can have an influence on mechanical properties.¹³ The reason for the increased level of monomeric conversion can be related directly to thermal vibration and the greater potential for initiator contact with the unreacted carbon groups. Specifically, decreasing the viscosity leads to a greater degree of composite resin polymerization.

A recent study demonstrated that increasing the composite curing temperature increased monomer conversion.¹⁴ Specifically, raising the temperature from 35°F (3°C) to 140°F (60°C) increased monomer conversion from 32% to 63% at a depth of 2 mm. This represents an increase in curing levels by nearly 100%. As one might expect, increasing the time of exposure to the curing light from 20 to 40 seconds minimized or eliminated any difference in conversion between the top of the specimen and a depth of 2 mm. The study demonstrated that the use of a 5-second exposure time of a pre-heated 130°F (54°C) composite resulted in a greater conversion rate than did a 40-second exposure used with a room temperature composite resin.

Fluidity as a Function of Filler Level and Preheating

In addition to the potential for increasing monomer conversion by preheating the composite resin, the preset fluidity can be increased. In fact, it has been shown that the reduction in viscosity by preheating is sufficiently greater to eliminate the need for a flowable composite resin liner (Personal communication, J. Broome, 2003). Fluidity increases of up to 75% over those evaluated at room temperature are clinically significant in terms of handling characteristics and adaptation to the walls of the cavity preparation.

While the flowable resins commonly exhibit excellent adaptability to the walls of the preparation, they unfortunately possess a number of undesirable characteristics that prevent them from being used in many clinical applications. These properties include higher polymerization shrinkage than conventional composite resins, lowered resistance to three-body wear, increased water sorption, and reduced elastic modulus.⁸ The use of a preheated composite resin of conventional composition that demonstrates temporary wetting characteristics of a flowable composite resin is an excellent approach for retaining all the properties imparted into contemporary posterior composite resin.

It is worth noting that the heating of a composite resin followed by cooling to body or even room temperature has no effect on the mechanical characteristics of the material.^{15,16} In fact, syringes that may have been preheated and then cooled to room temperature can be recycled an infinite number of times. In addition to maintaining optimum physical and mechanical characteristics, there should be a practical limitation on the shelf life of the material itself.

Clinical Application and Technique

Teeth #18(37) and #19(36) have interproximal caries that commonly would have been restored with the total-etch adhesive technique and placement of a thin layer of flowable composite on the gingival floor. More effectively, the restorative process is completed with a stronger universal hybrid-type composite (Figures 1 through 6). Prior to the insertion of the composite into the cavity preparation, the injection device (ie, Calset, AdDent, Inc, Danbury, CT) is heated to the appropriate temperature to reduce its viscosity.

With the advent of this heated injection device, the practitioner is able to eliminate the flowable composite and its less-than-ideal mechanical characteristics. Furthermore, the entire restoration will now consist entirely of a stronger and more durable hybrid composite resin. By elevating the composite resin temperature to 130°F

(54°C), the clinician can increase the flow of the composite by 80%, increase the depth of cure, and extend the level of polymerization.

Conclusion

The increase in the viscosity of composite resins provided an alternative to amalgam resins while increasing efficiency. This modification, however, led to a material that was porous and susceptible to the patient experiencing postoperative sensitivity. The system demonstrated herein, with its increased curing temperatures, has provided clinicians with an instrument that utilizes advanced composite resin technology while eliminating its key limitations. Further study will provide additional information regarding its long-term clinical success and applications.

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