

An alternative method to reduce polymerization shrinkage in direct posterior composite restorations

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Amalgam was the material of choice worldwide for Class I and Class II restorations for more than a century.¹ Its high strength, good wear resistance, technique insensitivity, low cost and adaptability for restoring small, medium and large lesions were responsible for this success.¹⁻⁶ A declining acceptance of amalgam among clinicians and patients, however, began in the early 1980s due to some inherent problems. For example, amalgam's corrosion and difficulty bonding to tooth structure, along with the necessity to remove sound tooth structure for retention, are problematic.^{7,8} Also at issue for some people are its lack of esthetics and fears about potential mercury toxicity.^{1,5-9} The need for amalgam alternatives has been a topic in the dental literature for several years.

To minimize the stress from polymerization shrinkage, efforts have been directed toward improving placement techniques, material and composite formulation, and curing methods.

Resin-based composites were advocated as a possible solution to this problem because they were mercury-free and thermally nonconductive, and they matched the shade of natural teeth and bonded to tooth structure readily with the use of adhesive systems. Historically, dentists who used resin-based composites to restore posterior teeth experienced poor wear resistance,

Background. Polymerization shrinkage is one of dental clinicians' main concerns when placing direct, posterior, resin-based composite restorations. Evolving improvements associated with resin-based composite materials, dental adhesives, filling techniques and light curing have improved their predictability, but shrinkage problems remain.

Methods. The authors propose restoring enamel and dentin as two different substrates and describe new techniques for placing direct, posterior, resin-based composite restorations. These techniques use flowable and microhybrid resin-based composites that are polymerized with a progressive curing technique to restore dentin, as well as a microhybrid composite polymerized with a pulse-curing technique to restore enamel. Combined with an oblique, successive cusp buildup method, these techniques can minimize polymerization shrinkage greatly.

Conclusions. Selection and appropriate use of materials, better placement techniques and control polymerization shrinkage may result in more predictable and esthetic Class II resin-based composite restorations.

Clinical Implications. By using the techniques discussed by the authors, clinicians can reduce enamel microcracks and substantially improve the adaptation of resin-based composite to deep dentin. As a consequence, marginal discoloration, recurrent caries and postoperative sensitivity can be reduced, and longevity of these restorations potentially can be improved.

difficulties in achieving good proximal contact and contour, polymerization shrinkage and poor dentin marginal adaptation.¹⁰⁻¹⁴ To avoid these shortcomings, indirect resin-based composite and ceramic inlays were introduced,¹⁵ spurring intensive research on resin-based composites.

In the past 10 years, a dramatic



improvement in newer-generation bonding agents and resin-based composite formulations has occurred. The improved performance of resin-based composites and the increasing demand for esthetics are encouraging more clinicians to select resin-based composites for posterior restorations.¹⁶⁻¹⁹ Although wear resistance of contemporary resin-based composites has improved significantly¹⁹⁻²² and good proximal contact and contour can be achieved,²³⁻²⁵ polymerization shrinkage remains the biggest challenge in direct resin-based composite restorations.²⁶⁻²⁹

METHODS AND MATERIALS

Polymerization shrinkage is responsible for the formation of a gap between resin-based composite and the cavity wall. This gap may vary from 1.67 to 5.68 percent of the total volume of the restoration,³⁰ and it may be filled with oral fluids. Oral fluids contain bacteria, which may be responsible for postoperative sensitivity and recurrent caries.³¹ When resin-based composites are cured, they shrink, and a residual polymerization stress is generated, which may be responsible for bonding failure. Stress from polymerization shrinkage is influenced by restorative technique, modulus of resin elasticity, polymerization rate, and cavity configuration or "C-factor." The C-factor is the ratio between bonded and unbonded surfaces³²; an increase in this ratio results in increased polymerization stress. Three-dimensional cavity preparations (Class I) have the highest (most unfavorable) C-factor because only outer unbonded surfaces absorb stress. To minimize the stress from polymerization shrinkage, efforts have been directed toward improving placement techniques, material and composite formulation, and curing methods.

Placement techniques and issues. *The incremental technique.* This technique is based on polymerizing with resin-based composite layers less than 2-millimeters thick^{33,34} and can help achieve good marginal quality, prevent distortion of the cavity wall (thus securing adhesion to dentin) and ensure complete polymerization of the resin-based composite. Following are variances related to differing stratifications:

- **Horizontal technique.**^{28,34,35} This technique is an occlusogingival layering generally used for small restorations; this technique increases the C-factor.
- **Three-site technique.**^{36,37} This is a layering

technique that is associated with the use of a clear matrix and reflective wedges. It attempts to guide the polymerization vectors toward the gingival margin.

■ **Oblique technique.** In this technique, wedge-shaped composite increments are placed to further prevent distortion of cavity walls and reduce the C-factor. This technique may be associated with polymerization first through the cavity walls and then from the occlusal surface to direct vectors of polymerization toward the adhesive surface (indirect polymerization technique).^{28,38}

■ **Successive cusp buildup technique.**³⁹⁻⁴¹ In this technique, the first composite increment is applied to a single dentin surface without contacting the opposing cavity walls, and the restoration is built up by placing a series of wedge-shaped composite increments to minimize the C-factor in 3-D cavity preparations. Each cusp then is built up separately.

Direct shrinkage. A chemically cured resin-based composite is used on the gingival floor in an attempt to direct the vectors of polymerization toward the warmer cavity walls. This should help to reduce the gap at the cervical margin.^{23,42,43}

Bulk technique. The bulk technique is recommended by some authors to reduce stress at the cavosurface margins.^{34,44} Some manufacturers recommend using this technique with packable composites even though this is not supported by a recent study.⁴⁵ Rueggeberg and colleagues⁴⁶ showed that the depth of cure does not exceed more than 2 mm when curing resin-based composites with modern light-curing units.

Resin-based composite materials. In the past 20 years, resin-based composites have been improved by reducing particle size, increasing filler quantity, improving adhesion between filler and organic matrix, and using low-molecular-weight monomers to improve handling and polymerization.^{8,47-51} By experimenting with particle size, shape and volume, manufacturers have introduced resin-based composites with differing physical and handling properties (Table 1). Microfill, hybrid, microhybrid, packable and flowable composites now are available to be used for varying clinical situations (Table 2).

Microfills. Microfills are 35 to 50 percent filled by volume and have an average particle size ranging from 0.04 to 0.1 micrometer. They have low modulus of elasticity and high polishability; however, they exhibit low fracture toughness and increased marginal breakdown.

TABLE 1

RESIN-BASED COMPOSITES CLASSIFICATION AND PHYSICAL PROPERTIES.					
COMPOSITE TYPE	AVERAGE PARTICLE SIZE (MICROMETERS)	FILLER PERCENTAGE (VOLUME %)*	PHYSICAL PROPERTIES†		
			Wear Resistance	Fracture Toughness	Polishability
Microfill	0.04-0.1	35-50	E	F	E
Hybrid	1-3	70-77	F↔G‡	E	G
Microhybrid	0.4-0.8	56-66	E	E	G
Packable	0.7-20	48-65	P↔G‡	P↔E‡	P
Flowable	0.04-1	44-54	P	P	F↔G‡

* Sources: Kugel,⁴⁷ Wakefield and Kofford⁵⁰ and Leinfelder and colleagues.⁵³
† E: Excellent; G: good; F: fair; P: poor.
‡ Varying among the same type of resin-based composite.

Hybrids. Hybrids are 70 to 77 percent filled by volume and an average particle size ranging from 1 to 3 μm . They do not maintain a high polish but do have improved physical properties when compared with microfills.

Microhybrids. Microhybrids are 56 to 66 percent filled by volume and have an average particle size ranging from 0.4 to 0.8 μm . They have particle

sizes small enough to polish to a shine similar to microfills but large enough to be highly filled, thus achieving higher strength. The results are resin-based composites with good physical properties, high polishability and improved wear resistance.

Packables. Packable composites are 48 to 65 percent filled by volume and have an average particle size ranging from 0.7 to 20 μm . Their improved handling properties are obtained by adding a higher percentage of irregular or porous filler, fibrous filler and resin matrix. They are indicated for stress-bearing areas and allow easier establishment of physiological contact points in Class II restorations. Research has shown that

TABLE 2

CLINICAL INDICATIONS OF RESIN-BASED COMPOSITES.	
COMPOSITE TYPE	CLINICAL INDICATIONS
Microfill	Enamel replacement in Class III, IV and V restorations Minimal correction of tooth form and localized discoloration
Hybrid	Posterior resin-based composite restoration Class V restoration Dentin build-up in Class III and IV restoration
Microhybrid	Posterior and anterior direct composite restoration Veneer Correction of tooth form and discoloration
Packable	Posterior resin-based composite restoration
Flowable	Pit and fissure restoration Liner in Class I, II and V restoration (dentin)

the physical properties of packable composites are not superior to conventional hybrids.⁵²⁻⁵⁴

Flowables. Flowable composites are 44 to 54 percent filled by volume and have an average particle size ranging from 0.04 to 1 μm . Their decreased viscosity is achieved by reducing the filler volume so they are less rigid, yet they are prone to more polymerization shrinkage and wear than conventional composites.^{47,55-57} Flowable composites have been said to improve marginal adaptation of posterior composites by acting as an elastic, stress-absorbing layer of subsequently applied resin-based composite increments.⁵⁸⁻⁶¹

Dentin-enamel adhesive systems. Since the introduction of the enamel-etching technique by

Buonocore⁶² in 1955, bonding to enamel has been considered a reliable procedure. Bonding to dentin, which was introduced more recently and has improved over the years, has become commonplace; early dentin-enamel adhesive systems, or DAS, bond strength to dentin ranged from 1 to 10 megapascals,⁶³ while contemporary DAS can achieve values of around 22 Mpa.⁶⁴

Two procedures widely used in bonding to tooth structure are the total-etch technique and the self-etching technique (primers and adhesives). The former is considered the gold standard for bonding and is achieved by etching enamel and dentin with 30 to 40 percent phosphoric acid. Bonding and mechanical retention are ensured by the penetration of resin into the microporosities of etched enamel and by the formation of a hybrid layer and resin tags as a consequence of resin penetration on demineralized peritubular, intertubular and intratubular dentin.⁶⁵⁻⁷² Self-etching primers and adhesives are a simplification of enamel-dentin bonding procedures with demineralization, priming and resin concentrated into one material. This is an attempt on the part of manufacturers to give dentists a DAS that is easy to manipulate, saves time and is less technique-sensitive. In most cases, long-term clinical evaluations are needed for validation.⁷⁰⁻⁷⁶

Curing methods. In 1984, Davidson and colleagues³⁰ stressed the importance of having composite flow in the direction of the cavity walls to allow for maximum internal adaptation during the early setting phase of composite. Two studies demonstrated that the relief of polymerization stress through composite flow is reached with the use of low-light energy; conversely, they recorded higher polymerization shrinkage with higher light energy.^{77,78} Miyazaki and colleagues⁷⁷ demonstrated that composite exhibited improved physical properties when cured at a low intensity and with slow polymerization vs. higher intensity and faster polymerization. Since then, studies have reported improved marginal adaptation and physical properties of resin-based composite using this technique, aptly named “soft-start” polymerization.⁷⁹⁻⁹⁰

Plasma arc, argon laser curing lights used to polymerize resin-based composites decrease exposure time and increase depth of cure when compared with conventional curing lights.⁹¹ Increased resin brittleness and polymerization shrinkage, poor physical properties and the

degree of polymerization, however, make this light source’s effectiveness questionable.⁹²⁻⁹⁵ Blue light-emitting diode curing lights are being studied and may present another option for resin-based composite polymerization.^{96,97}

DISCUSSION

Most composite placement techniques introduced in the past 20 years were based on the concept that resin-based composite shrinks toward the light and employed this theory to attempt to favorably direct the vectors of polymerization. Versluis and colleagues⁹⁸ demonstrated that the direction of polymerization contraction is more influenced by the quality of the adhesion and the C-factor, than by the position of the light source. Losche⁹⁹ pointed out that the optimal results obtained by using some of these placement techniques (three-site and indirect polymerization) are related to a reduction in light transmission rather than the direction of the polymerization vectors. The inability of reflective wedges to ensure the polymerization of composites¹⁰⁰ and the difficulties in obtaining a good proximal contact¹⁰¹ have contributed to clear wedges’ loss of popularity. Furthermore, the introduction of new light-curing methods has contributed to the decline in use of the three-site technique. Similarly, the results of the directed shrinkage technique are, at best, controversial.^{57,102-104}

On the other hand, the successive cusp buildup technique^{25,39-41} has not received a lot of attention in the literature, but it is an interesting concept that, when used appropriately, can minimize the development of stress at the tooth-resin interface. This technique is performed by strategically placing successive layers of wedge-shaped composite to decrease the C-factor ratio. Wedge-shaped composite increments are 1- to 1.5-mm, triangular apico-occlusal layers of uncured composite that are condensed and sculpted directly in the preparation using a composite instrument (Figure 1 and Figure 2). Liebenberg^{25,39,40} stressed that the first layer must be very thin and applied to a single dentinal surface without contacting opposing cavity walls. The cavity is completely filled with wedge-shaped composite increments, and each cusp then is built up separately.

Development of new techniques. We use a placement technique similar to that described by Liebenberg³⁹ but with some modifications. We use a pulse-curing technique to polymerize composite at the enamel cavosurface margins and a

progressive curing technique to polymerize composite dentin increments; when also using the selective composite technique, we select different composite materials to restore dentin (flowables and microhybrids) and enamel (microhybrids). We found that the technique we use can help reduce enamel microcracks and improve the adaptation of the composite to deep dentin while achieving high esthetics and function.

It is our goal to continue to improve the prognosis of posterior resin-based composite restorations in an era in which dentists are not afraid to use resin-based composites in the posterior regions. On the other hand, the ADA's recommendations¹⁸ for posterior resin-based composite restorations are being stretched in clinical practice because patients may not be able to afford the ideal indirect restoration in situations involving large posterior restorations.²⁵

Pulse curing to reduce enamel microcracks. It is universally accepted that the marginal seal generally can be preserved around enamel cavosurface margins with contemporary adhesive systems.^{68,70,105} It is difficult to ensure perfect marginal adaptation either at gingival or occlusal enamel cavosurface margins. Enamel is a highly mineralized tissue and has a modulus of elasticity higher than that of dentin, resulting in a lower flexibility and decreased ability in relief of shrinkage stress. When bonding composites to enamel, two unfavorable events may happen: poor marginal adaptation and seal occur due to incorrect application of bonding adhesive, and the bonding interface remains intact but microcracks develop just outside the cavosurface margins due to the stress of polymerization shrinkage.^{82-84,106-11} This latter phenomenon is particularly common in high-C-factor restorations (unfavorable ratio of bonded and unbonded surfaces in the restoration)³² and may be increased by use of high-modulus composites as they may transmit more polymerization shrinkage forces to the tooth. Microcracks represent a way for microleakage to occur, and the use of a composite sealer may delay this phenomenon only partly.

To reduce microcracks, clinicians can control the rate of polymerization, alter placement technique and choose composite that have the appropriate modulus of elasticity. The reduction of the C-factor throughout the application of a microhybrid composite to a single-bonded surface and the pulse polymerization of each enamel composite increment may help reduce microcracks drasti-

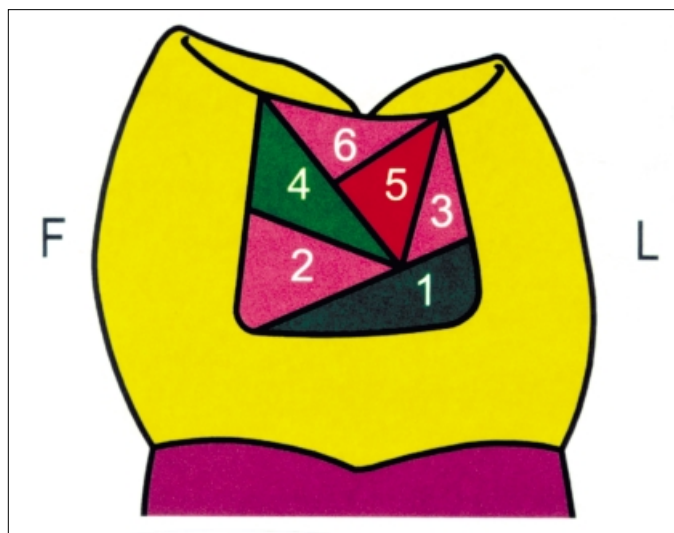


Figure 1. Schematic representation of wedge-shaped composite increments (1-6) used to build up the enamel proximal surface. F: Facial aspect. L: Lingual aspect.

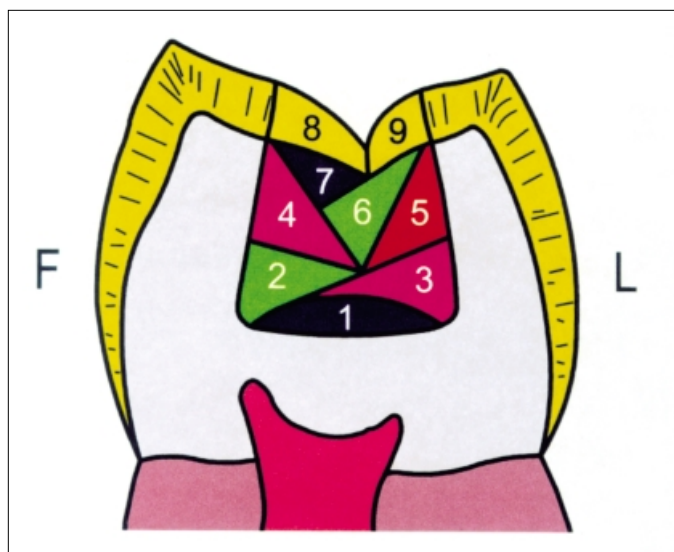


Figure 2. Schematic representation of the flowable composite increment (1) and wedge-shaped increments (2-7) used to build up dentin; two increments (8 and 9) are used to build up enamel using the successive cusp buildup technique. F: Facial aspect. L: Lingual aspect.

cally. The pulse technique initially uses low-intensity curing for a short period to provide sufficient network formation on the top composite surface while delaying the gel point in the depth underneath until final high-intensity polymerization is started. It then uses a conventional mode for the building of dentinal composite increments with a specific energy density for each composite.⁸²⁻⁸⁴

TABLE 3

RECOMMENDED PHOTOCURING INTENSITIES AND TIMES FOR ENAMEL AND DENTIN BUILDUP.

BUILDUP LOCATION	COMPOSITE SHADE (PRODUCT NAME)*	POLYMERIZATION TECHNIQUE	INTENSITY (MW/CM ²)*	TIME (SECONDS)§
Proximal Enamel	Pearl Smoke Pearl Neutral/Pearl Frost (Vitaescence)	Pulse	200 (300)	3 (40)
Dentin	A2 (flowable, PermaFlo) A3.5-A3-A2-A1 (Vitaescence)	Progressive curing	(300)	(40)
Occlusal Enamel	Pearl Smoke/Pearl Neutral/Pearl Frost Trans Smoke/Trans Mist/Trans Frost (Vitaescence)	Pulse	200 (600)	3 (10 [occlusal], 10 [facial], 10 [palatal])

* Vitaescence and PermaFlo are manufactured by Ultradent Products Inc., South Jordan, Utah.

† mW/cm²: Milliwatts per square centimeter.

‡ Intensity at first polymerization (intensity after waiting period).

§ Photocuring time at first polymerization (time after waiting period).

A classical soft-start polymerization also may be used, but the advantages of this alternate curing mode have not been thoroughly investigated. Mehl and colleagues⁸⁰ and Ernst and colleagues⁸⁸ found that the variable curing method can improve marginal integrity with different composites when cured with a soft-start polymerization, while Friedl and colleagues¹¹² and Bouschlicher and colleagues¹¹³ did not find any improvement using the same soft-start polymerization method. This result may be explained by the varied amount and concentration of photoinitiators. Certain resin-based composites may require shorter exposure time to get the same degree of conversion while maintaining the same intensity. As a matter of fact, the gel point is anticipated even with a soft-start polymerization. Yoshikawa and colleagues¹¹⁰ recently demonstrated composite improved marginal adaptation using a soft-start polymerization; however, enamel microcracks still were present and unaffected.

The pulse polymerization technique is based on the same principle as soft-start polymerization, but it is applied with a different modality, which may be less technique-sensitive to composites' chemical variation.¹¹⁴ Pulse polymerization should be used not only in the enamel occlusal cavosurface margins, but also at the cervical enamel margin to reduce microcracks at this critical area. To correctly apply this pulse-curing technique, clinicians should use a light-curing unit with pro-

grammable time and intensity (VIP Light, Bisco Inc., Schaumburg, Ill.; Spectrum 800, Dentsply/Caulk, Milford, Del.).

Enamel buildup: proximal surface. In Class II restorations, the enamel proximal surface is built up first through the application of different wedge-shaped composite increments using an oblique layering technique while being careful to avoid having a single composite increment be in contact with opposing cavity walls. Each composite increment is pulse-cured with a low-intensity light for a short duration (depending on the type of composite and depth of the preparation) followed by a waiting time of three minutes to allow for strain relief. During this three-minute waiting time, a thin layer of flowable composite is applied to a single surface in the dentin pulp floor and axial wall of the preparation to reduce the C-factor and help avoid cusp deflection due to stress from polymerization (Figure 2). At this point, the resin-based composite restoration's proximal surface and the flowable composite are cured together at once at a higher intensity using a progressive curing technique (Table 3). Final polymerization of the composite restoration's proximal surface and the flowable composite is completed at higher intensity (Table 3). If more than one tooth is to be restored at one appointment, another restoration can be started during the three-minute waiting time following the procedure described previously.

Progressive curing technique. To completely fill

the dentin, wedge-shaped composite increments are placed using the stratified layering technique in which a higher chroma is placed in the middle of the preparation and a lower chroma is placed close to the cuspal walls^{41,115} (Figure 2). Each composite dentin increment is cured using a progressive curing technique (40 seconds at 300 milliwatts per square centimeter instead of a conventional continuous irradiation mode of 20 seconds at 600 mW/cm²) (Table 3). Lower light intensity and longer curing time have resulted in an improvement in marginal adaptation while maintaining the excellent physical properties of the composite.^{77,78}

Enamel buildup: occlusal surface. The restoration is completed when the final composite increments are layered onto the enamel cavosurface margins. Each cusp is built up separately without contacting the opposing ones and is pulse-cured separately (three seconds at 200 mW/cm²). Secondary anatomy is created before a final polymerization at a higher intensity is applied (30 seconds at 600 mW/cm²) (Table 3). This technique allows the dentist to create anatomically correct morphology by using the outlying cavosurface margins as a guide for composite sculpturing. Occlusion adjustment usually is minimal or not necessary, which saves the dentist time and preserves the wear of posterior composites.^{116,117}

Selective composite technique. A goal of the selective composite technique is to use different combinations of composite materials to restore enamel and dentin. Enamel is a highly mineralized tissue and contains 92 percent inorganic hydroxyapatite by volume. Dentin is only 45 percent inorganic and is arranged in an organic matrix that consists primarily of collagen. It is crossed by dentinal tubules running from the dentinoenamel junction to the pulp. Variations in tubule size, as well as direction and number of tubules, are responsible for regional variations in dentin structure. Bonding resin-based composite to the dentinal surfaces is considerably more complex and less reliable than bonding resin-based composite to acid-etched enamel.^{118,119} It also has been demonstrated that when bonding to deep dentin, a decrease in bond strength may occur.¹²⁰⁻¹²⁴ This may explain the adhesive failure at the dentin-composite restoration interface even though high-bond strength and tight composite to acid-etched enamel seal are achieved. As a consequence, composite can be deformed under occlusal load and thermal stress.¹²⁵

Since enamel and dentin are different substrates, they should be restored with different resin-based composite materials. Cervical and occlusal enamel are restored using a microhybrid resin-based composite that has a wear pattern and modulus of elasticity closer to that of enamel than other resin-based composites. Dentin has a modulus of elasticity lower than enamel and the use of an intermediate elastic layer may be indicated.¹²⁶⁻¹²⁸ The combination of a filled adhesive and a flowable composite may help create an elasticity gradient between the dentin and the microhybrid composite; thus, the flowable composite may improve the effectiveness of the dentin bonding agent in counteracting the polymerization stress at the restoration-dentin interface. Hannig and Friedrichs¹²⁵ and Belli and colleagues¹¹¹ reported successfully using flowable composite when it was placed in dentin exclusively; however, its use for both enamel and dentin has been questioned and has yielded ambiguous results.^{57,90}

The following case report provides a sequence of clinical procedures we used when placing direct Class II restoration following our technique.

CASE REPORT

An 18-year-old woman complained of increased tooth sensitivity on her maxillary right first molar (Figure 3). Clinical and radiographic analyses revealed caries in the mesial surface extending to the dentin. To restore the tooth, we selected a microhybrid composite (Vitaescence, Ultradent Products Inc., South Jordan, Utah) that had a large variety of enamel shades that mimic tooth structure. Different microhybrid composites (Esthet-X, Dentsply/Caulk; Point 4, Kerr, Orange, Calif.; Amelogen, Ultradent Products Inc.) that are based on the natural layering technique^{129,130} also could have been used. All four of these composite systems provide a variety of shades that mimic dentin and enamel surfaces of young, adult and geriatric patients.

After local anesthesia was achieved in the patient, we placed a rubber dam. As the partially erupted second molar would not ensure predictable stability, we positioned the dental dam clamp on tooth no. 3. We removed the caries using a no. 330 carbide bur (759, Ultradent Products Inc.) and rounded sharp angles with a no. 4 bur and a no. 6 bur (767 and 768, Ultradent Products Inc., respectively). The cavity preparation was completed when we placed a gingival butt joint



Figure 3. Preoperative occlusal view of tooth no. 3.



Figure 5. A matrix was placed to protect adjacent tooth structure during cavity preparation and etching. Then etching was performed using 35 percent phosphoric acid.

with no bevel on the axial or occlusal surface using a 330 carbide bur (Figure 4). Adjacent tooth structure was protected during preparation with a matrix (InterGuard, Ultradent Products Inc.) (Figure 5).

We disinfected the preparation using a 2 percent chlorhexidine antibacterial solution (Consepsis, Ultradent Products Inc.), acid-etched enamel and dentin for 15 seconds with 35 percent phosphoric acid (Ultra-Etch, Ultradent Products Inc.), removed the etchant and water sprayed the preparation for 30 seconds being careful to maintain a moist surface. We placed a fifth-generation, 40 percent filled ethanol-based adhesive system (PQ1, Ultradent Products Inc.) in the preparation, gently air-thinned it until the milky appearance disappeared (Figure 6) and light-cured it for 20 seconds using a curing light.

We placed a sectional matrix (Composi-Tight, Garrison Dental Solution, Spring Lake, Mich.), a plastic wedge (Flexi Wedge, Garrison Dental Solu-

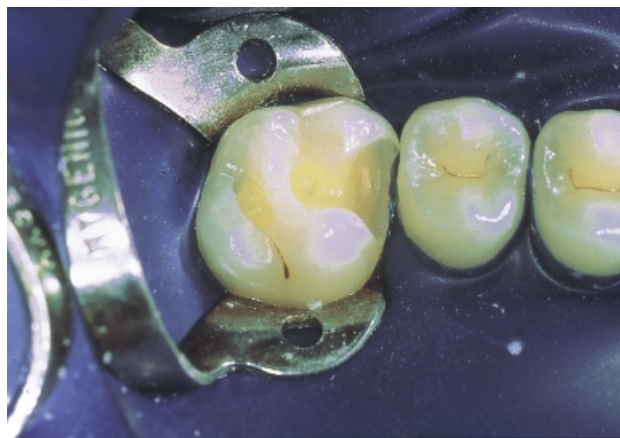


Figure 4. Tooth no. 3 after a rubber dam was placed, caries was removed and the cavity preparation was completed with a gingival butt joint and no bevel either on the axial or occlusal surface.

tion) and a G-ring to reconstruct the mesial surface (Figure 7). We burnished the matrix against the adjacent tooth and built up the enamel proximal surface using the Pearl Neutral, or PN, enamel shade of the microhybrid composite in an oblique fashion without contacting opposing cavity walls (Figure 8). We pulse-cured each layer for three seconds at 200 mW/cm². We then removed the sectional matrix, plastic wedge and G-ring; placed a thin layer of the A2 shade of the flowable composite (PermaFlo, Ultradent Products Inc.) in the deepest portion of dentin, applying it to a single surface (Figure 9); and light-cured flowable and microhybrid composites for 40 seconds at 300 mW/cm². We completely filled the dentin using a combination of A3.5, A3 and A2 dentin shades of the microhybrid composite throughout by applying wedge-shaped composite increments using the stratified layering technique (Figure 10) and the progressive cure technique.

We completed the restoration by applying PN microhybrid composite to the enamel cavosurface margins. We built up each occlusal surface separately without having it contact the opposite cusp and pulse-cured them at 600 mW/cm² separately for three seconds (Figure 11, page 1396) before a final polymerization at a higher intensity (30 seconds at 600 mW/cm²). We removed the dental dam, checked the occlusion and polished the restoration using the Finale (Ultradent Products Inc.) polishing system. We etched the restoration's cavosurface margins with 35 percent phosphoric acid and sealed them with a composite sealer (PermaSeal, Ultradent Products Inc.) (Figure 12, page 1396).

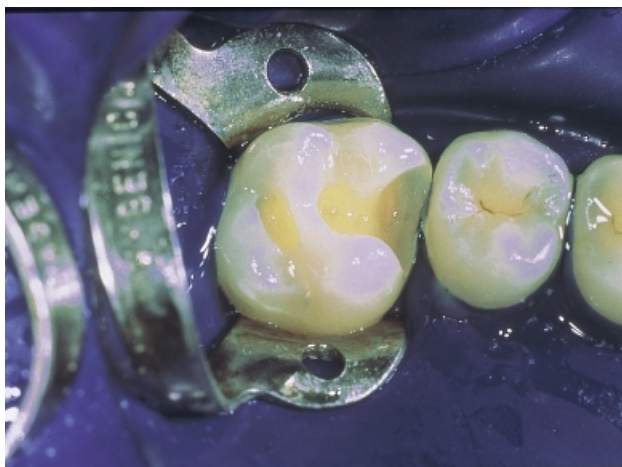


Figure 6. Enamel's and dentin's glossy appearances after application of a fifth-generation, 40 percent filled ethanol-based adhesive system.

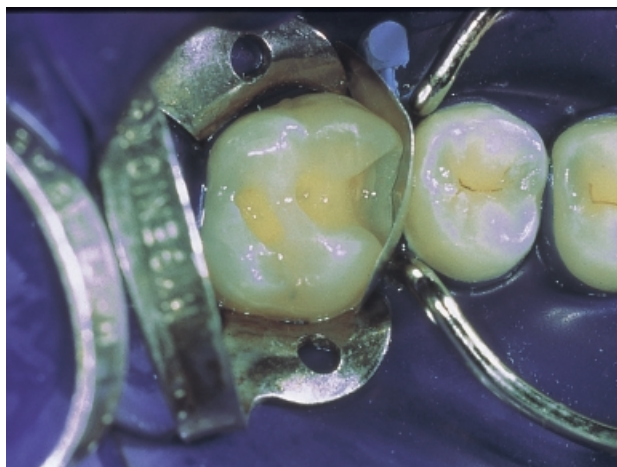


Figure 7. A sectional matrix, plastic wedge and G-ring placed to reconstruct the proximal surface.

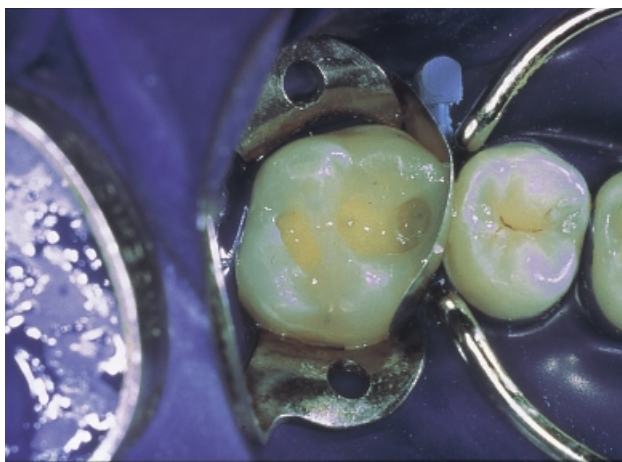


Figure 8. Tooth no. 3 after the enamel proximal surface was built up using the Pearl Neutral enamel shade of the microhybrid composite (Vitaescence, Ultradent Products Inc., South Jordan, Utah).

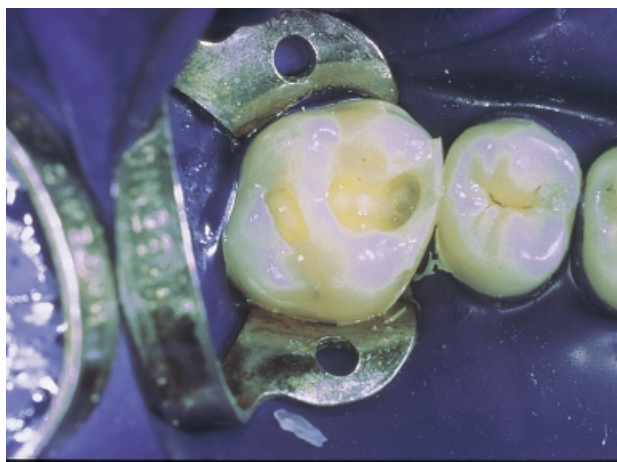


Figure 9. Tooth no. 3 after the sectional matrix, plastic wedge and G-ring were removed and the A2 shade of the flowable composite (PermaFlo, Ultradent Products Inc., South Jordan, Utah) was applied to a single dentin surface.

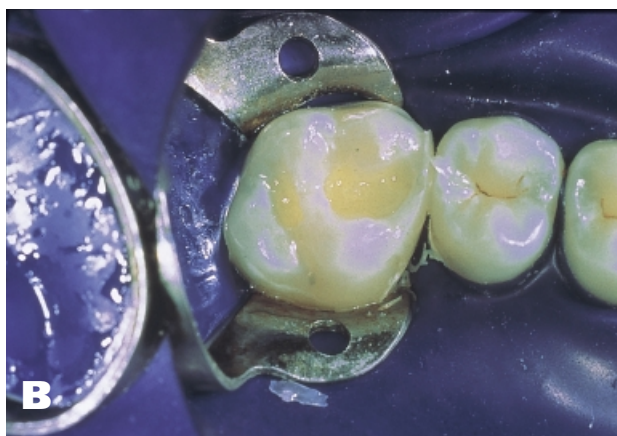
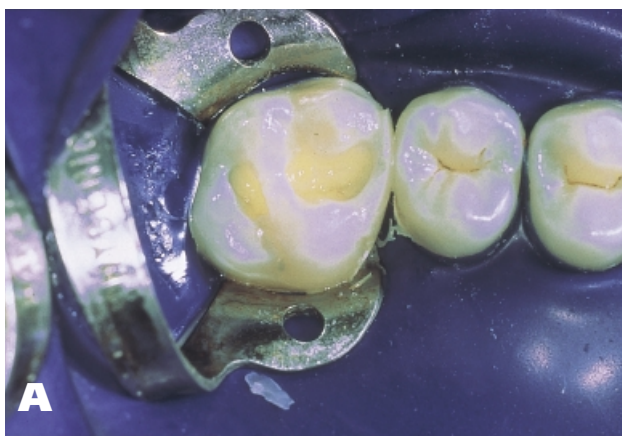


Figure 10. A and B. Tooth no. 3 after wedge-shaped composite increments of A3.5, A3 and A2 shades of the microhybrid composite (PermaFlo, Ultradent Products Inc., South Jordan, Utah) were used to reconstruct dentin.

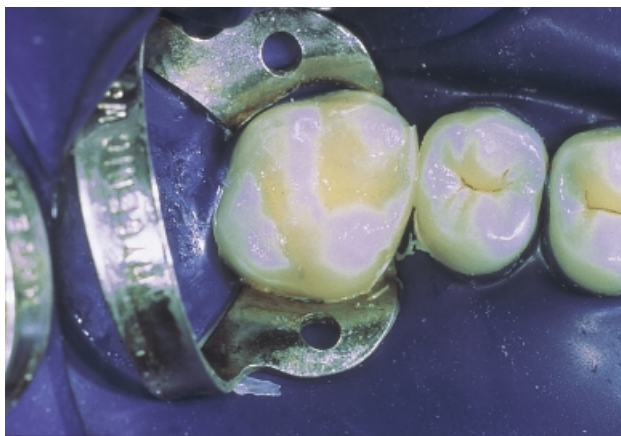


Figure 11. Tooth no. 3 after Pearl Neutral enamel shade of the microhybrid composite (VitaIescence, Ultradent Products Inc., South Jordan, Utah) was used to build up the occlusal surface according to the successive cusp buildup technique.

CONCLUSION

Research is under way to develop resin-based composite materials with novel monomers, new photoinitiators and improved particle systems to reduce polymerization stresses. In this article, we outlined principles for the judicious selection and use of modern dental materials, careful control of polymerization shrinkage, and effective placement techniques that can be used to create more predictable and esthetic Class II resin-based composite restorations. ■

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Figure 12. Postoperative occlusal view of tooth no. 3.

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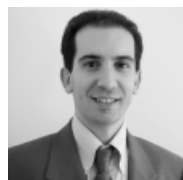
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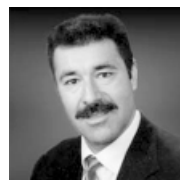
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