Dimensions of Color: Creating High-Diffusion Layers with Composite Resin

CE 1

Abstract: *The objective of this article is to provide the clinician with fundamental principles for achieving success with directly placed composite resin restorations in posterior teeth. It describes the adhesive technique and protocol for the development of tooth-colored composite restorations in the posterior dentition by integrating the concepts of function, form, and color. A case presentation demonstrates the anatomical stratification and proper placement of tints and opaquers for the development of the direct posterior composite resin-bonded restoration. Used with an understanding of tooth morphology, restorative material selection, color options, and the physical properties of light, these techniques allow optimally esthetic restorations to be predictably achieved.*

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A good leader voraciously studies history in an attempt to learn from the mistakes of the past. To fully understand the historical progression of a nation, a people, an industry, or a company, one must look at all of the layers of history. Like a good leader, a good clinician must visualize the dentition not as a single unit, but as an anatomic stratification with successive layers of dentin, enamel, and incisal components, as well as a wealth of color shades, tints, and characteristics of opacity and translucency. The history of dentistry teaches that each new discovery concerning the anatomical composition helps the clinician learn from the single views of the past and move forward to the development of the polychromatic stratification technique.

Traditionally, the hybrid composite resin was used for its strength and fracture resistance, whereas the microfill was necessary to attain not only improved polishability, but to maintain the durability of the polish. However, it was soon discovered that this process of stratification—which used the attributes of both the hybrid and the microfill to create an optimal restoration with enhanced mechanical properties—provided another advantage; a variation in the shades and opacities of color which created the illusion of three-dimensionality—the "polychromatic effect."[1,2]

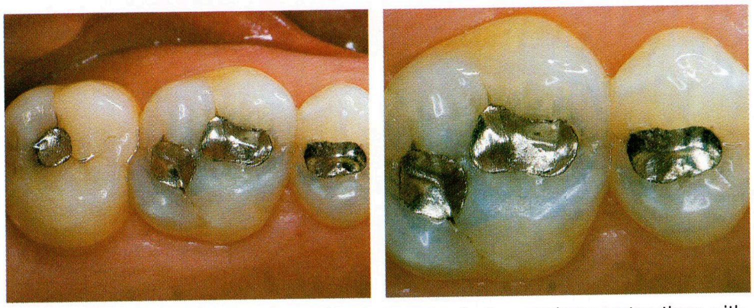
By using an anatomic stratification with successive layers of dentin, enamel, and incisal composite,[3] a more realistic depth of color may be achieved,[4] as well as surface and optical characteristics that mimic nature.[5] Thus, past clinical and scientific efforts and requirements to create a more ideal restorative material for function and anatomical form resulted in the development of color within a tooth.

Metallic restorative materials, such as gold and amalgam, required the restorative dentist to be concerned solely with function and form. The development of tooth-colored restorative materials requires clinicians to address an additional aspect—color. Unfortunately, many clinicians continue to use yesterday's techniques and procedures with today's newer adhesive restorative materials. With advances in material sciences and adhesive technology, the restorative concept has solidified a modern variable in the equation—esthetics. Inherent in the development of an esthetically pleasing restoration is a thorough knowledge and understanding of the complexities of color, because color can make the difference between an average restoration and an optimal esthetic result.[6,7] In this new equation, "form follows function,"[8,9] and "anatomical form defines color."[6] While form has been described in three dimensions (ie,

Learning Objectives

After reading this article, the reader should be able to:

- discuss the fundamental principles for achieving success with directly placed composite resin restorations in posterior teeth.
- describe the adhesive technique and protocol for the development of tooth-colored composite restorations in the posterior dentition by integrating the concepts of form, function, and color.
- define the roles of tooth morphology, restorative material selection, color variation, and the physical properties of light in predictably achieving optimally esthetic restorations.



Figures 1A and 1B—Preoperative occlusal view of defective amalgam restorations with recurrent decay.

height, length, and width),[10-12] color provides a more complex analysis of the primary and secondary optical properties of both the tooth and the restorative material. The successful determination and transfer of color to an esthetic reproduction of the natural dentition depends on the clinician's understanding of the interrelation of these optical properties to the anatomical morphology of the tooth. The modern restorative clinician can use earlier concepts of function and form and integrate them with knowledge of color and anatomical morphology to create natural, tooth-colored restorations. This process requires an anticipation of the final function, form, and color to achieve an optimal esthetic result.

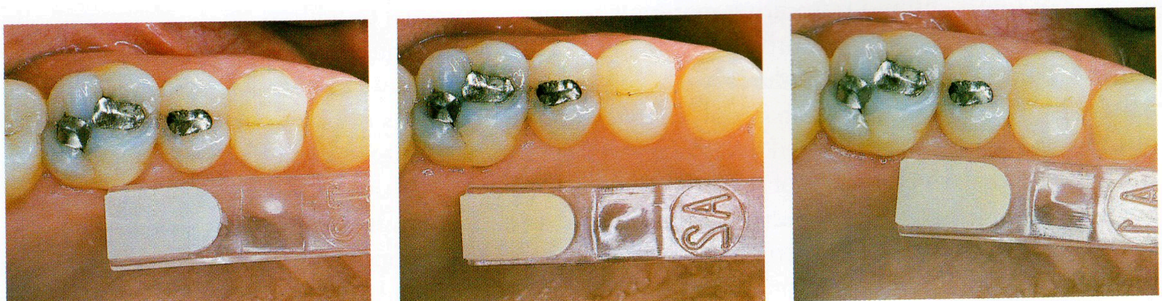
The objective of this article is to provide the clinician with fundamental principles for achieving success with directly placed composite resin restorations in posterior teeth. It describes the adhesive technique and protocol for the development of tooth-colored composite restorations in the posterior dentition by integrating the concepts of function, form, and color. A case presentation demonstrates the anatomical stratification and proper placement of tints and opaquers for the development of the direct posterior composite resin-bonded restoration. Used with an understanding of tooth morphology, restorative material selection, color options, and the physical properties of light, these techniques allow optimally esthetic restorations to be predictably achieved.

Understanding and Developing Color

The successful determination and creation of color in an esthetic restoration depends on understanding and interpreting color. The Swiss painter Johannes Itten described color by writing "Whoever would become a master of color must see, feel, and experience each individual color and the endless number of their combinations with all other colors. Colors are capable of spiritual-emotional expression."[13] Because the compositional and emotional effects of color cannot be rationally measured,[1] a knowledge of color and the different optical properties of the components of the tooth must be developed. In natural polychromatic teeth, differing colors are distributed, and various optical characteristics are observed through the enamel and dentin. This polychromatic effect manifests in different optical characteristics, and relationships between these characteristics and their roles in the natural dentition must be properly interpreted so that esthetic restorations can be fabricated. Thus, a broader definition of color is necessary based on anatomy, optical properties, and polychromaticity to appropriately describe tooth color and esthetics. This definition is based on the natural dentition and the relative contribution of dentin and enamel to color. Dentin and enamel have dramatically different optical properties, and the contributions of each should be considered separately during shade determination. Muia described color in four dimensions—hue, chroma, value, and translucency.[7] In addition to these dimensions, color was redefined to include more subtle optical properties.[7] These secondary properties include translucency, opacity, opalescence, iridescence, fluorescence, and surface gloss, and all contribute significantly to the total esthetics and vitality of the tooth and the restoration, and are influenced by surface morphology.[6]

Stratification of Color

Understanding the stratification process



Figures 2A through 2C—Shade selection was performed before rubber-dam placement with the Venus™ 2Layer™ shade system.

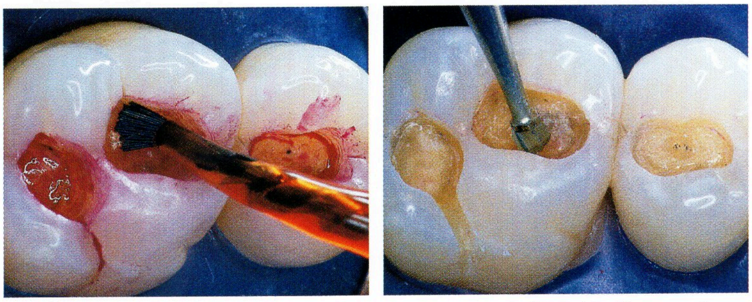
requires a knowledge of the optical properties of color and the anatomical morphology of the tooth. In a cross-section of the clinical crown, there is a three-dimensional variation in the structure of the dentin and the enamel layers. In natural teeth, differing colors are distributed and various optical characteristics are observed throughout the enamel and dentin, which renders the tooth polychromatic.[1] This polychromatic effect is evident in various optical characteristics: hue, chroma, value, translucency, opalescence, iridescence, fluorescence, and surface gloss. The relationships between these different optical characteristics and their role in the natural dentition must be properly interpreted to fabricate esthetic restorations.[14]

By using an anatomic stratification with successive layers of dentin, enamel, and incisal composite, a more realistic depth of color may be achieved, as well as surface and optical characteristics that mimic nature.

While previous generations of composite resin systems were designed to produce tooth-colored and translucent restorations with a single filling material, the entire restoration had to be filled with one shade, and multiple shades or modifiers were then incorporated to provide color adjustments. Because no single monochromatic composite resin can duplicate the complex orientation of the color evident in the natural dentition, it is necessary to select various colors for the artificial enamel and the artificial dentin layers. Accordingly, to reconstruct the natural polychromatic effect, the layers cannot be stratified in a uniform layer of equal dimension such as in plexiglass, which is uniformly distributed in layers, but requires an irregular, undulated placement of variations of composite resin colors. This allows the optical properties of light passing through the natural tooth and the restoration to reflect, refract, absorb, and transmit according to the optical densities of the hydroxyapatite crystals, enamel rods, dentinal tubules, and restorative material, thus rendering the tooth multicolored.[15]

Determining Shades and Modifiers

Because composite does not have hydroxyapatite crystals, enamel rods, and dentinal tubules, the final composite restoration requires the clinician to develop an illusion of the way light is reflected, refracted, transmitted, and absorbed



Figures 3A and 3B—Removal of carious tooth structure as indicated by the reapplication of caries-detecting dye.

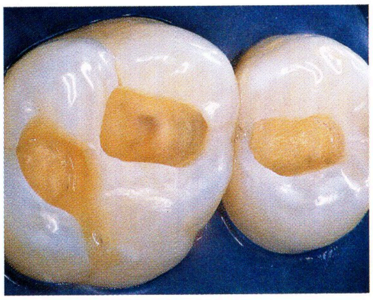


Figure 4—Completed preparation.

Figure 5—A 0.5-mm bevel was placed on the linguogingival cavosurface margin.

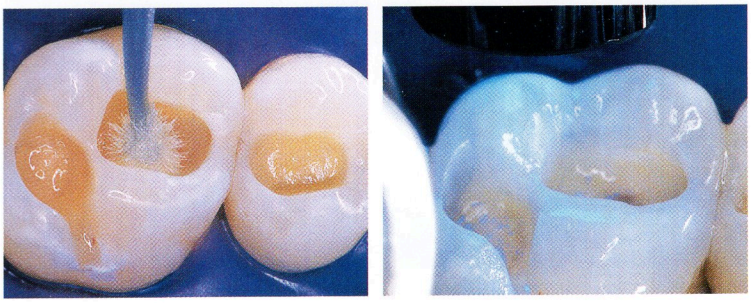
by these dentin and enamel microstructures when restoring the occlusal surface.[15] Re-creating the occlusal surface requires a similar orientation of enamel and dentin. Newer formulations of composite resins possess most of the optical properties that render the tooth polychromatic. Dentin shades are available in a variety of shades and translucencies, and enamel shades that are highly translucent, fluorescent, and opalescent have been developed. Color modifiers and opaquing resins also are available, which make an infinite number of color combinations possible.

Layering concepts have evolved using the optical properties of the tooth as a reference for composite evaluation.[16] The layering concept attempts to reproduce the color and esthetics of the tooth using the optical properties of dentin and enamel shades in varying combinations along with color modifiers and opaquers. However, the successful determination and transfer of color to an esthetic restoration still depends on the clinician's understanding and interpretation of color and its relationship to the anatomical morphology of the tooth. The limitations of current composite restorative materials must also be understood.

Most of the tooth color "occurs" in the dentin. The dentin layer contains varying distributions of yellow, orange, and red, and remains thickest at the gingival and middle thirds of the anterior teeth. Earlier-generation

Figure 6—The preparations were cleaned with 2% chlorhexidine.

Figure 7—The preparations were etched for 15 seconds with 35% orthophosphoric acid semigel.



Figures 8A and 8B—A single-component adhesive was applied with a disposable applicator for 20 seconds with a continuous motion, reapplying every 5 seconds, and light-cured for 20 seconds.

composite resin shades were designed to produce the entire tooth color and translucency with a single filling material. To produce esthetic restorations with these materials, it may be necessary to fill the entire restoration with one shade or make adjustments in color with multiple shades or modifiers. On labial surfaces, dentin shades are used in the upper two thirds of the tooth and incisal shades are used in the incisal third. When selecting dentin shades, it is important to also consider opacity. Opaque dentin shades, in addition to strength,[17] provide the chroma needed to determine the ultimate shade. It is often necessary to extend this layer to the dentinoenamel junction to "hold" the shade. Otherwise the final restoration will appear darker, or lower in value.

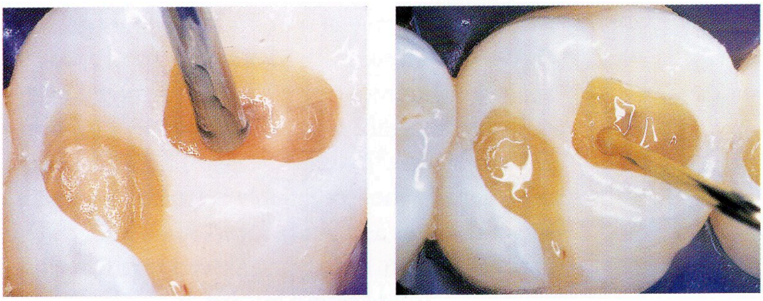
Enamel shades contribute significantly to the total esthetics of a restoration. Tooth enamel is virtually colorless,[7] but it possesses many of the optical properties that contribute to the vitality of the tooth—translucency, fluorescence, opalescence, and gloss.[6] These characteristics are exemplified on the cuspal tips and marginal ridges of posterior teeth as well as on the incisal edges and proximal incisal surfaces of anterior teeth. The enamel layer, which has a white or gray appearance, remains thickest at the incisal edge of anterior teeth and thinnest at the cervical region. Modern enamel shades have high translucency, are fluorescent and opalescent, and maintain a clinically stable, higher surface gloss.[18] The clinician must understand that enamel shades tend to reduce the value of a restoration and cannot be used to anatomically replace human enamel.[6] Enamel shades can be used on incisal edges and cuspal surfaces, but the shade of the restoration ultimately depends on dentin shades. If enamel shades are used to cover the entire labial surface, it must be layered and used sparingly at the cervical third.

Because of the variety of colors and their orientation within natural teeth, selecting appropriate shades of composites remains difficult. Because no single monochromatic composite resin can duplicate the complex orientation of the colors seen in the natural dentition, the clinician must be able to select a variety of appropriate shades of composite resin.[19] Arbitrary and subjective shade designations, such as "universal," "yellow," or "light," further complicate the process of shade selection. Because most standard composite resin shade guides are manufactured from unfilled methacrylates, they do not accurately represent the true shade, translucency, or opacity of the final polymerized restorative material.[20] Also, many of the composite resins are synchronized to the Vita® Lumin Shade Guide[a], which was designed for porcelain, not resins. Considering the need for further refinement in almost all shade guides, both the clinician and the ceramist may benefit from the fabrication of custom shade tabs because they are made from the material itself.[21-25]

Many clinicians continue to use yesterday's techniques and procedures with today's newer adhesive restorative materials.

A new development by Heraeus Kulzer for a more accurate shade guide with composite resin can be found in the Venus™ 2Layer™ shade system.[21] Using a custom-fabricated, layered shade guide of polymerized composite resin, each shade tab is hand-layered with an opaque dentin layer and encased with a superficial layer of enamel corresponding to the specific shade. On request, the manufacturer provides the clinician with additional empty tabs that can be used to create individual patient shade tabs. This system of shade fabrication may help the

[a] Vita Zahnfabrik, Germany, distributed in US by Vident™, Brea, CA 92621; 800-828-3839



Figures 9A and 9B—A flowable composite resin is applied as a cavity liner with a syringe applicator and uniformly distributed with a rounded condenser, then light-cured for 20 seconds.

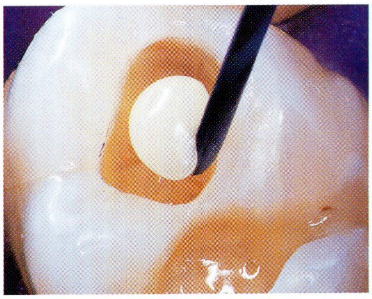


Figure 10—The artificial dentin layer, an opacious A2 shaded hybrid composite (Venus™), is applied in increments.

clinician to create "true color" as it appears in the natural dentition.

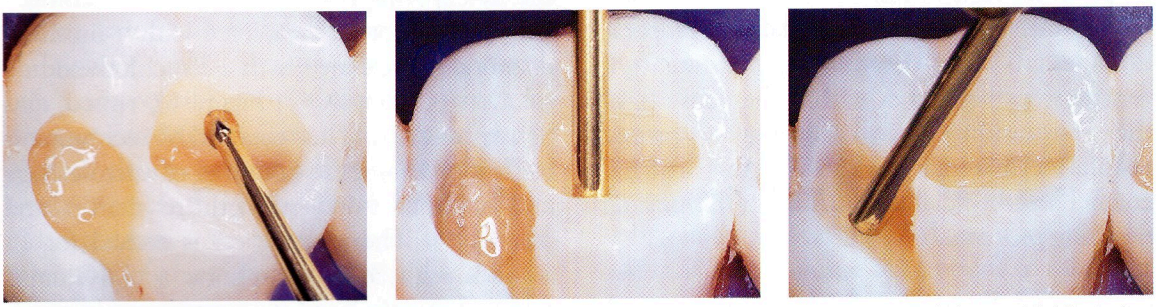
Because composite resins are not available in all of the shades necessary to match natural dentin and enamel colors, the use of tints is required in the stratification process to adjust hue and chroma to lower value, and to establish natural characteristics for a specific area of the tooth. In addition, the placement of tints over the dentin-colored composite and beneath the artificial enamel enhances the realistic distribution of color throughout the restoration. The existing resins are generally translucent and are colored with either pigments or dyes to achieve the desired optical effect. Opaquers, designed to block the light with titanium dioxide and similar pigments, can either conceal underlying discolorations or duplicate areas that are difficult to match (eg, hypocalcification).[6]

> A knowledge of color and the different optical properties of the components of the tooth must be developed.

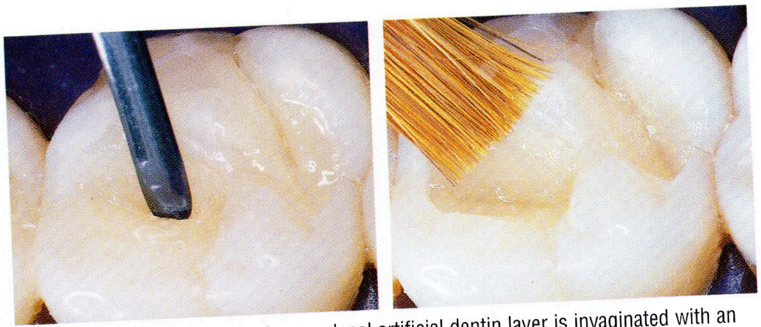
Using the broader definition of color, including secondary optical properties such as translucency, fluorescence, opalescence, surface gloss, and the relationship of color to anatomical morphology, the clinician can create more esthetic, lifelike restorations. During the fabrication process, the clinician develops a working knowledge of the optical properties of absorption, reflection, refraction, transmission, dispersion, diffraction, and interference of composite resins and the inherent differences from the natural dentition. Further, the clinician understands the relation of the properties of composite resins, tints, and opaquers to the characteristics of the natural dentition. The case study demonstrates a methodological protocol for the incremental application of composite resins, tints, and modifiers using this knowledge. It also describes the adhesive technique and protocol for the development of tooth-colored composite restorations in the posterior dentition by integrating the concepts of function, form, and color.

Preoperative Considerations

The teeth to be restored with direct composite were the maxillary left first and second molars and the second bicuspid, which had existing amalgam restorations (Figures 1A and 1B). Before administering anesthesia and rubber-dam isolation, the preoperative occlusal stops and excursive guiding planes are recorded with articulation paper and transferred to a hand-drawn occlusal diagram, then recorded on an intraoral or digital camera, or indicated and reviewed on a stone model. This diagram acts as a restorative road map for the clinician and can include information such as dentin and enamel intercolor contrasts, translucency patterns, craz-



Figures 11A through 11C—Each artificial dentin layer is applied in increments using a lateral condensation technique and light-cured for 40 seconds.



Figures 12A and 12B—A final preocclusal artificial dentin layer is invaginated with an interproximal instrument and smoothed with a sable brush.

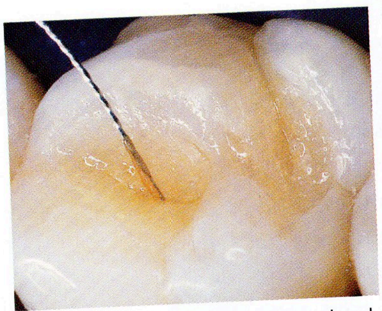


Figure 13—A diluted ochre tint was placed with an endodontic file into the final invagination of the body layer and light-cured for 40 seconds.

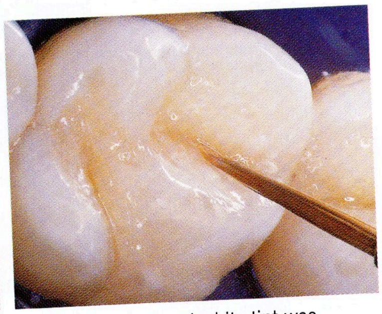


Figure 14—A diluted white tint was applied to create a natural transition between the occlusal planes and high-valued tooth structures.

ing, hypocalcification spots, incisal and gingival blending, and occlusal stain patterns. The clinician may also be able to determine anatomic morphological details, such as developmental grooves and the shape of embrasures, as well as prominences, convexities, facets, angles, plane areas, or any other characteristics that can provide helpful information when reconstructing the tooth surfaces. Additionally, a preoperative selection of composite resins, tints, and modifiers, with their shades and orientations, is recorded. Shade selection should be accomplished before rubber-dam placement to prevent improper color matching as a result of dehydration and elevated values (Figures 2A through 2C).[26] When teeth dehydrate, air replaces the water between the enamel rods, changing the refractive index that makes the enamel appear opaque and white.[15] The use of a color-corrected daylight source of 5,500 K is necessary for proper color registration.[27]

This initial registration is valuable in preparation design when determining placement of centric stops beyond or within the confines of the restoration, when determining proper restorative material thickness of the artificial enamel and artificial dentin, and in minimizing finishing procedures.[28]

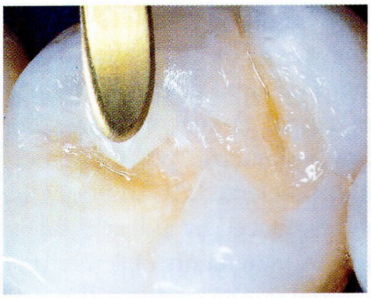
Restorative Sequence

After anesthesia is administered, the treatment site is isolated with a rubber dam to achieve adequate field control and protect against contamination.[29,30] Upon removal of the existing amalgam restoration, a caries-disclosing solution (Seek®/Sable™ Seek®,[b]) helps to detect and identify the irreversibly infected carious tissue and serves as a guide for its removal.[31,32] The carious dentin can be removed with a slow-speed #6 carbide round bur (such as a Midwest[c]) and spoon excavators (Figures 3A and 3B).

The occlusal outline is extended only to include carious enamel, provide access to the carious dentin, remove any residual amalgam staining, and provide access for the application of restorative materials (Figure 4). Healthy tooth structure should be removed only when the occlusal outline requires extension to a point beyond or within the previously indicated functional stops.[28] The adhesive preparation design requires maximum preservation of remaining tooth structure; there is no extension for prevention.[33-39] The preparation is limited to access to the lesion or defect because composite requires less volume to resist clinical fracture than amalgam.[37,40] The width of the preparation should be as narrow as possible because the wear resistance of the restoration is a direct function of dimension.[41] Also, increased buccolingual width of the preparation can invade into the centric holding areas.

To allow for a better resin adaptation, all internal line angles should be rounded and cavity walls should be smooth.[36] The occlusal cavosurface margin should not be beveled because it may increase the width of the preparation and infringe on the centric holding area, increasing the wear rate of the restoration.[41] Beveling should be restricted to the gingival and proximal margins when there is enamel present to increase the potential for bonding (Figure 5). This increases the fracture resistance by increasing the bulk of the restoration, increases the bonding surface area, and decreases microleakage by exposing the enamel rods for etching.[42] The preparation is completed with a finishing diamond and cleaned with a 2% chlorhexidine solution (Consepsis®,[b]) (Figure 6), rinsed, and lightly air-dried. The "total etch" technique is used to minimize the potential of microleakage and enhance bond strength to dentin and enamel.[43-45] The preparation is etched for 15 seconds with 35% phosphoric acid (Gluma[c]

[b] Ultradent Products, Inc, South Jordan, UT 84095; 800-552-5512
[c] DENTSPLY® Professional, a division of DENTSPLY® International, York, PA 17404; 800-989-8826



Figures 15A and 15B—A neutral, translucent-shaded (T2) Venus™ composite was sculpted with a curved metal instrument and smoothed with a sable brush.

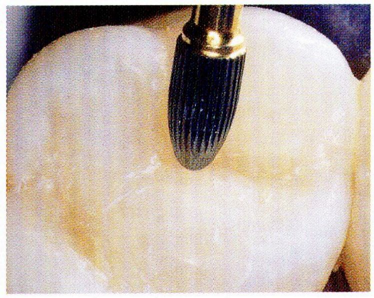


Figure 16—The occlusal anatomy was refined using #12 and #30 fluted, egg-shaped finishing burs.

Etch 35 Gel[d]) (Figure 7), rinsed for 5 seconds, and gently air-dried for 5 seconds. A single-component adhesive (Gluma® Comfort Bond + Desensitizer[d]) is applied with a disposable applicator for 20 seconds with a continuous motion, reapplying every 5 seconds. Any excess is removed with the applicator, and the agent is air-thinned for 5 seconds and light-cured (with the Translux® CL[d]) for 20 seconds (Figures 8A and 8B). Although a small amount of excess adhesive can be applied over the margins to improve sealing, this excess should be removed during finishing procedures.

Dentin and enamel have dramatically different optical properties.

While pulp tissues have demonstrated the inherent ability to repair, heal, and form reparative mineralized bridges under several restorative materials, recent studies reveal that the failure of composite restorations may be related to the sealing and adaptation of the tooth–restorative interface.[46,47] Bacterial infiltration and microleakage have been attributed to pulpal inflammation and necrosis of exposed vital dentin, regardless of the restorative material selected.[46,48] However, the use of nonadhesive restorative materials (eg, calcium hydroxide) as a protective agent may generate a gap at this interface, resulting in a colonization by bacteria and/or action as a hydraulic pump, stimulating the flow of tubular fluid inward. This pressure may be responsible for postoperative sensitivity on mastication.[46,49,50] The hybridization of the exposed dentin with an adhesive system effectively protects this pulp–dentin interface, provides resistance to microleakage, and allows retention of the restoration, regardless of the depth of the preparation.[46,51-54]

[d] Heraeus Kulzer, Inc, Armonk, NY 10504; 800-431-1785

Internal Adaptation

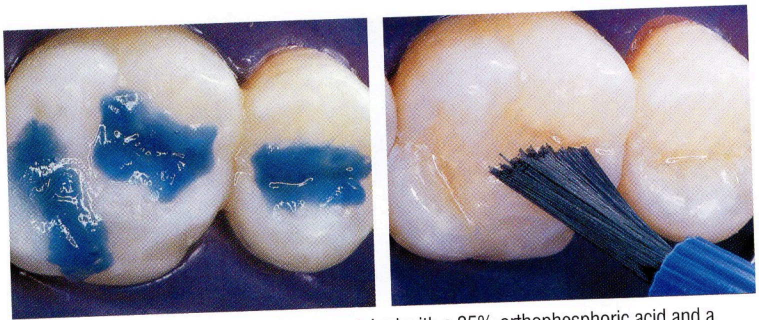
The use of flowable composite resin as a stress-absorbing lining material between the adhesive system and the restorative composite resin has been suggested for large restorations.[55] The combination of flowables and viscous composite ensures a more intimate contact with the dentin bonding agent because of the lower viscosity, and has resulted in enhanced internal adaptation.[56] Because of the low modulus, these composites buffer the polymerization shrinkage stress by flow, which theoretically eliminates cuspal deformation or gap formation and reduces microleakage.[57] Therefore, if the elastic modulus is low, the composite will stretch to accommodate the inherent modulus of the tooth, and the internal layer may absorb the polymerization shrinkage stress of the resin composite by elastic elongation.[51,58] Also, these lower-viscosity flowables may enhance the wetting capacity[56] of the restoration, resulting in a more complete interfacial internal adaptation and reducing the formation of voids that can contribute to a weakened surface and microleakage.

An A3 shaded flowable composite resin (Flowline®,[d]) is injected as the syringe tip is slowly removed, and uniformly distributed with a rounded condensor (M-1-TN[e]) (Figures 9A and 9B). This technique reduces the possibility of entrapping bubbles and ensures optimal adaptation of the resin material to the adhesive interface.[59] A small increment, 1 mm to 2 mm thick, is applied to the pulpal floor of the class I cavity and on the gingival floor of the proximal preparation, then light-cured for 20 seconds using the Translux®,[d] light device.

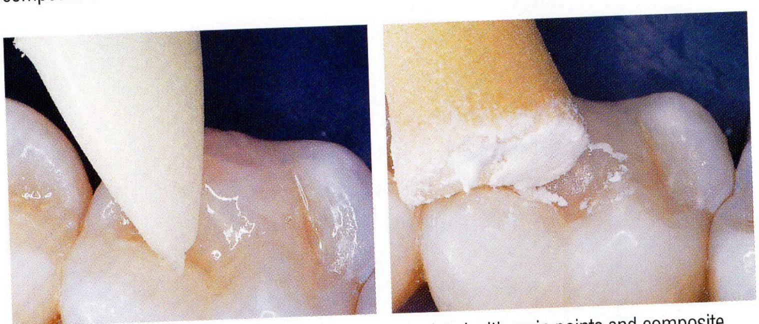
Incremental Stratification Technique

Incremental layering has been advocated for use in large composite restorations to avoid the limitation of depth of cure, reduce the effects of

[e] Cosmedent®, Inc, Chicago, IL 60611; 800-621-6729



Figures 17A and 17B—The margins were etched with a 35% orthophosphoric acid and a composite surface sealant was applied and cured to seal any cracks or microscopic porosities.



Figures 18A and 18B—The final polishing was completed with resin points and composite polishing paste.

polymerization shrinkage, and enhance the esthetic results from the multilayering of color.[60,61] However, it is the anatomy of the tooth that should guide the clinician in developing the correct interpretation of form and color. Incremental layering with successive layers of artificial dentin and artificial enamel composite shades provides a more realistic depth of color. To enhance the optical characteristics of light diffusion and refraction, a thin layer of resin can be applied between the artificial enamel and artificial dentin to allow light to pass through the high translucent layer within the internal aspects of the restoration.[62] The polychromatic effect is achieved by stratifying variations in shades and opacities of the restorative composite. Because of the variations in natural teeth, the combinations of different composite shades have to be applied in relationship to the natural tissue anatomy and specifically adapted to individual clinical situations. The following technique uses both the incremental layering of composite and the stratification of color to create a natural chromatic integration.[63]

Developing the Artificial Dentin Layer

The cavity preparation is filled incrementally, using an opacious A2 shaded hybrid composite (Venus™,d) from the preoperative shade-mapping diagram (Figure 10). Each increment is gently condensed with a clean, nonsticking composite condenser to ensure complete adaptation to the underlying resin and tooth structure. Each increment is light-cured for 40 seconds using the Translux® light device. To reduce the possibility of cuspal flexure, a composite hybrid with a low volumetric polymerization shrinkage should be selected.[64] Additionally, this problem may be reduced by a diagonal layering of the hybrid in increments of 1 mm and feathering the material up the cavity wall in a V shape (Figures 11A through 11C).[65,66] Opposing enamel walls should not be contacted by the same increment[67] to minimize the wall-to-wall shrinkage and thus reduce intercuspal stress.[68] The application of the composite in oblique layers results in fewer contraction gaps at the margins. The composite resin should be condensed and shaped to correspond to cusp development and dentin replacement.

When the artificial dentin layer is developed, a final preocclusal layer is invaginated with an interproximal instrument (TNCVIPC[f]) while still soft (Figures 12A and 12B). It is important to anticipate the final result and not invade the final artificial enamel zone, and to allow space for the overlying translucent enamel shade. A thin layer of resin can be applied and cured to create a "light diffusion layer" and provide an illusion of depth for restorations of limited thickness. This translucent layer will cause an internal diffusion of light and control luminosity within the internal aspects of the restoration.[62] The internal characteristics (creation o pits and fissures, staining of grooves, or the cre ation of internal color within the restoration are applied using a #08 endodontic file or fin sable brush. An ochre-tinted resin is applied i the previously formed invagination to corre spond to the preoperative shade diagram (Figur 13). If the chroma is too high, it can be dilute with an untinted resin and a small brush c removed with a clean applicator tip. The tin and the final dentin layer are polymerized for 4 seconds using the Translux® light. These tin should be polymerized before placing addition stratification materials to stabilize the chara terization and prevent color mixing. A smoot natural transition can be obtained between th occlusal planes and the higher-valued too structures using a diluted white tint, and a necessary staining can be developed at this tin (Figure 14). This color variation allows t development of a three-dimensional appe ance within the restoration.

[f] Hu-Friedy® Mfg Co, Chicago, IL 60618; 800-483-7433

Developing the Artificial Enamel Layer

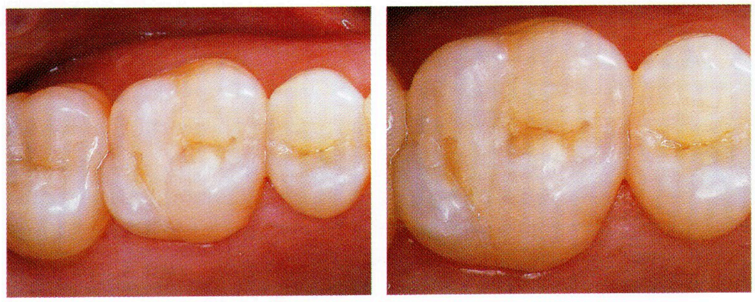
To allow space for the proper enamel thickness and position, the definitive esthetic result should be visualized during the development of the artificial dentin and internal characterization stages. The enamel or the artificial enamel layer is the principal determinant of the value of the tooth or the restoration[7] and can be varied by the thickness of this layer. The enamel is colorless, but through its network of rods it acts as a fiber-optic conduit and projects the underlying color found in the dentin. The small-particle hybrid (Venus™) used in developing the restoration in this case has three translucent shades. The T1 shaded composite is a cool blue translucency, the T2 shaded composite is a neutral translucency, and the T3 shaded composite is a yellow translucency. In this case, T2 is sculpted with a curved metal instrument and smoothed with a sable brush to reproduce form in addition to the optical effects of enamel (Figures 15A and 15B). This procedure will provide esthetic translucency and allow the development of functional and anatomical occlusal morphology. Developing the restoration in increments and considering the occlusal morphology and occlusal stops allows the clinician to minimize finishing procedures[28] and results in a restoration with improved wear and clinical performance with fewer microstructural defects.[41,66]

Developing the restoration in increments and considering the occlusal morphology and occlusal stops allows the clinician to minimize finishing procedures.

After placing the last layer of composite and before the final cure, a glycerin oxygen inhibitor (DeOx®,b or Insure™,e) is applied in a thin layer with a brush to the surface of the restoration and light-cured for a 2-minute postcure, because the longer the composite is subjected to the curing light, the more effective the cure.[34,69]

Finishing and Polishing

As discussed previously, a thorough preoperative occlusal registration and careful shaping of the composite resin to those confines before curing facilitates the establishment of anatomic morphology and minimizes the finishing protocol.[28] However, a proper, meticulous finishing protocol may increase the longevity of the restoration.[70,71] To reproduce the shape, color, and luster of the natural dentition[72] while enhancing the esthetics and longevity of the restoration, the following protocol can be implemented.



Figures 19A and 19B—The postoperative occlusal view reveals the harmonious integration of composite resin with natural tooth structure to create natural esthetics.

To replicate the natural anatomical form and texture, the initial contouring was performed with a series of finishing burs. The occlusal refinement is achieved with #12 and #30 fluted, egg-shaped finishing burs (BluWhite Diamond Kit®,g) while closely observing the tooth–resin interface and using a dry protocol (Figure 16). After the initial finishing procedure, the margins and surface defects were sealed. All accessible margins were etched with a 35% orthophosphoric acid gel (Gluma® Etch 35 Gel), rinsed, and dried. A composite surface sealant (OptiGuard™,g) was applied and cured to seal any cracks or microscopic porosities that may have formed during the finishing procedures (Figures 17A and 17B). The use of a surface sealant has been shown to reduce the wear rate of posterior composite resin restorations.[41,73] Polishing was initiated with light-cured resin points (Enhance® finishing points[h]) impregnated with an abrasive that permitted surface defects to be effectively eliminated. The final polish was performed with regular and extrafine composite resin polishing paste (Prisma® Gloss™/Prisma® Gloss™ Extrafine[h]) and an Enhance® foam cup[h] (Figures 18A and 18B). The rubber dam was removed and the patient was asked to perform closure without force and then centric, protrusive, and lateral excursions. Any necessary occlusal equilibration was accomplished with #12 and #30 egg-shaped finishing burs and the final polish was repeated. The contact was tested with unwaxed floss to ensure the absence of sealant in the contact zone. The margins were then visually inspected with surgical telescopes.

The surface quality of the composite is influ-

[g] Kerr® Corporation, Orange, CA 92867; 800-537-7123
[h] DENTSPLY® Caulk®, Milford, DE 19963; 800-LD-CAULK

enced not only by the polishing instruments and polishing pastes, but also by the composition and the filler characteristics of the composite.[5,74,75] The newer formulations of composites with smaller particle sizes, shapes, and orientations provide a level of polishability that compares to porcelain and enamel.[26] Although clinical evidence of polishability with these new small-particle hybrids appears promising, the long-term durability of the polish will need to be evaluated in future clinical trials.

A proper, meticulous finishing protocol may increase the longevity of the restoration.

The postoperative result achieved through the use of incremental stratification of composite resin reflects the harmonious integration of function, form, and esthetics (Figures 19A and 19B).

Conclusion

This article has attempted to demonstrate an incremental stratification technique that uses an adhesive design concept with a small-particle hybrid composite to develop anatomically correct morphology while creating the internal color of the natural dentition. This technique provides the restorative clinician with a means of integrating traditional restorative concepts of function and form with an understanding of color and anatomical morphology for the development of the third element of the restorative equation—esthetic restorations.

Clinicians accustomed to the materials and procedures of 20 years ago should adapt to the newer restorative materials and a new restorative concept. The restorative equation has become one of achieving and displaying restorations of beautiful, natural-looking teeth that will maintain function and structural integrity while eliminating the appearance of metals, such as gold and amalgam, during smiling or phonation.[5] Manufacturers' improvements in the physical and optical properties of restorative materials allow the clinician to create functional and esthetic harmony. These advancements in restorative materials and adhesive technology require following an adhesive design concept when considering preparation design, restorative material selection, and placement techniques and procedures. The ability to visualize and re-create dentin not as a single unit, but as an anatomic stratification of layers and colors, allows the clinician to provide restorations with an illusion of three-dimensionality consistent with the surrounding natural dentition.

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