Developing Form, Function, and Natural Aesthetics With Laboratory-Processed Composite Resin—Part II

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Although the literature has provided clinicians with some awareness of restorative material alternatives, such as laboratory-processed composite resin, these systems are not yet fully understood and implemented in daily practice, despite their benefits to dental patients. Whereas part I highlights treatment planning, preparation design, and impression making for an indirect resin onlay, this article emphasizes the laboratory fabrication as well as the involved adhesive bonding and finishing protocols. Additionally, it presents considerations for the selection of either indirect resin- or porcelain-based materials.

Learning Objectives:

This article emphasizes the laboratory fabrication and adhesive bonding and finishing protocols. Upon reading this article, the reader should:

- Gain an understanding of the development of a posterior onlay fabricated of an indirect composite resin system.
- Define the factors for selection of restorative materials for intracoronal restorations (porcelain and processed composite resin).

Key Words: indirect, resin, adhesive, posterior, finishing

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Recent innovations in adhesive systems and procedures, technology, and materials have resulted in the increased utilization of bonded restoratives. These adhesive materials allow dental professionals to re-establish the function, shape, and contour of the teeth, to replicate color, to achieve natural light transmission, and to recapture strength and aesthetics through conservative adhesive tooth preparation designs. This has resulted in a myriad of opportunities for the discriminating patient and has provided solutions to many of the restorative challenges faced by the clinician.

Part II of this article demonstrates the further laboratory and clinical development of a posterior onlay fabricated of an indirect composite resin system (ie, belleGlass NG, Kerr/Sybron, Orange, CA). It will describe the components and the specific material properties of this next-generation indirect composite resin system. This part will conclude with a discussion of the factors for restorative material selection.

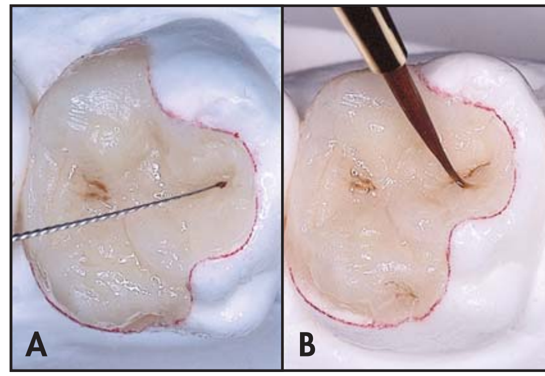

Figure 1A. A brown-tinted resin is applied with an endodontic file and light cured. 1B. An ochre tint is applied into the occlusal and lingual grooves.

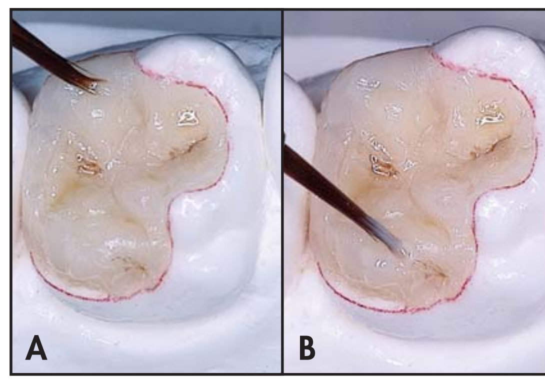

Figure 2A. An infinitesimal amount of diluted gray tint is placed. 2B. A diluted white tint is placed along the incline planes and cusp tips.

Laboratory Procedure

Internal Color Characterization

Once the dentin layer was developed,[1] an invagination was made with a long-bladed instrument to form central, lingual, and buccal grooves while the material was still malleable. A thin layer of resin was then applied and cured to create a "light diffusion layer" and to provide an illusion of depth for the restoration.[2]

Pits, fissures, and grooves were then rendered, and a brown-tinted resin was applied in the previously formed invaginations according to the shade diagram and light cured for 40 seconds (Figure 1A). This tint was polymerized prior to the placement of additional stratification materials to stabilize the characterization and prevent mixing of colors. To create a warm internal hue, an ochre tint was diluted with an untinted resin and applied into specific occlusal and lingual grooves and light cured (Figure 1B). In order to recreate the natural translucency of enamel, a gray tint was applied in a thin wash on the distal marginal ridge area and other specific regions and light cured for 40 seconds (Figure 2A). A smooth, natural transition was developed between the occlusal planes and the higher-valued tooth structures using a diluted white tint (Figure 2B). These internal characterizations emphasized the tooth form and instilled the restoration with a three-dimensional effect.

The Artificial Enamel Layer

To establish a more realistic depth of color, the "artificial enamel" was applied in two layers of varying thicknesses. The first enamel layer was applied as the outer envelope on the buccal and lingual surfaces and contoured with a long-bladed composite instrument and then smoothed with an artist's sable brush. Surface irregularities were carefully eliminated, and the increment was light cured for 40 seconds. The final artificial enamel was restored with small increments of a light-shaded composite resin (ie, belleGlass NG, Kerr/Sybron, Orange, CA), which was placed over the developed anatomical contours as an occlusal envelope to reproduce form in addition to the optical effects of enamel (Figure 3A). As discussed previously,[1] preoperative occlusal registration and careful shaping of the composite resin to those confines before curing facilitated the establishment of anatomic morphology and minimized the finishing protocol.

The onlay remained on the working die and was placed in the curing unit at 135°C with a pressure of 60 psi to 80 psi or 41.369 N/cm^2 in a nitrogen atmosphere for 20 minutes. The elevated temperature and nitrogen gas increased the polymer conversion, and the pressure allowed the oxygen to be purged out of the system in three cycles.

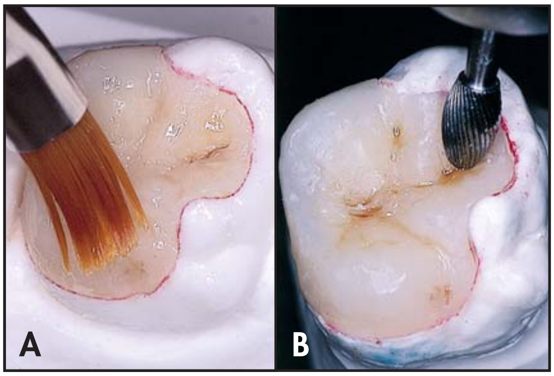

Figure 3A. The "artificial enamel" layer is developed with a light-shaded resin. 3B. An egg-shaped finishing bur is used to contour the occlusal surface.

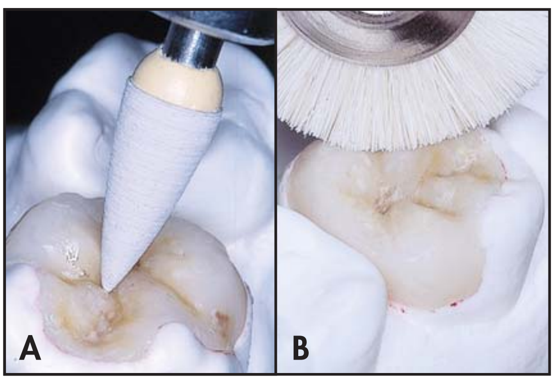

Figure 4A. The final polish is initiated with silicone rubber points. 4B. The definitive luster is accomplished with a soft, white, goat-hair brush and composite polishing paste.

Laboratory Finishing Procedure

The laboratory finishing procedure was critical for enhancing the aesthetics and longevity of the restored teeth by affecting wear resistance[3] and marginal integrity.[4] The premature interproximal contacts were marked on the solid master model with articulating paper. The onlay was placed on the working die, and the interproximal surface was adjusted with a rubber wheel (ie, Composi Pro 1 Step, Brasseler USA, Savannah, GA); its flat surface was used for minor adjustments while polishing the contact zone.

Gingival and proximal contouring was accomplished with a series of short-tapered, straight-edge finishing burs (ie, ET-3, Brasseler USA, Savannah, GA). Shaping and contouring of the occlusal surface or any minor modifications in the occlusion were performed with an egg-shaped finishing bur (eg, OS1, Brasseler USA, Savannah, GA; 9406, BluWhite Diamond, Kerr/Sybron, Orange, CA), which conformed to the appropriate curvature of the tooth surface (Figure 3B). Initial polishing of the occlusal surface was accomplished with silicone pointed brushes that reached into the occlusal grooves and prepolish and high-shine rubber points (eg, DC1M, DC1, Diacomp, Brasseler USA, Savannah, GA) following the occlusal anatomical contours (Figure 4A). Final polishing of the occlusal surface of the restoration was rendered with diamond pastes and goat-hair brushes applied at conventional speed. The final surface gloss was achieved with a dry cotton buff (ie, Ceroshine, Brasseler USA, Savannah, GA) using an intermittent motion applied at conventional speed (Figure 4B).

Adhesive Surface Preparation

The authors' standard cementation protocol for indirect composite resins includes microetching and silane application to restore any coating on the original fillers that may have been removed by sandblasting (Figure 5). The silane acted as a coupling agent between the filler particles on the indirect resin surface and the resin cement. Use of CoJet (ie, 3M Espe, St Paul, MN), a tribochemically assisted bonding system, is designed to create potential micromechanical retention and a chemical bond between composite resin cement and the indirect resin surface.[5] The mechanism of action enabled silicate particles to become embedded in the surface of the restoration during sandblasting, which then reacted with the silane to improve bond strength.[6]

Adhesive Protocol and Finishing

Once anesthesia had been administered, a spoon excavator was used to remove the provisional restoration. The cavity preparation was cleaned with hand and sonic instruments (Figure 6), and the preparation was rinsed thoroughly. The onlay was tried in for the evaluation of color and marginal adaptation. Its interproximal contact was inspected and necessary equilibrations were made. The tooth was isolated with a rubber dam to protect against contamination and to achieve adequate field control, at which time the "total etch" technique was utilized to minimize the potential of microleakage and enhance bond strength to dentin and enamel (Figures 7 and 8).[7-9]

After the internal aspect of the inlay was conditioned, the restoration was cemented with the dual-cure composite (ie, Nexus 2, Kerr/Sybron, Orange, CA). The restoration was seated firmly in place, and the excess cement was removed with a sable brush. It was imperative to leave some residual cement to prevent voids and to compensate for the polymerization shrinkage of the cement. The initial polymerization was for 20 seconds. Glycerin was applied to all the margins to prevent the formation of an oxygen-inhibition layer on the resin

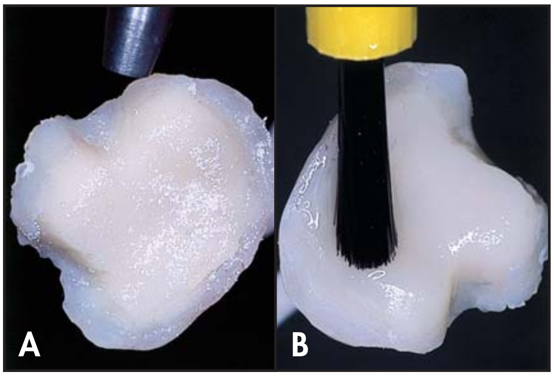

Figure 5A. The internal surface of the composite restoration is microetched. 5B. Silane is then applied.

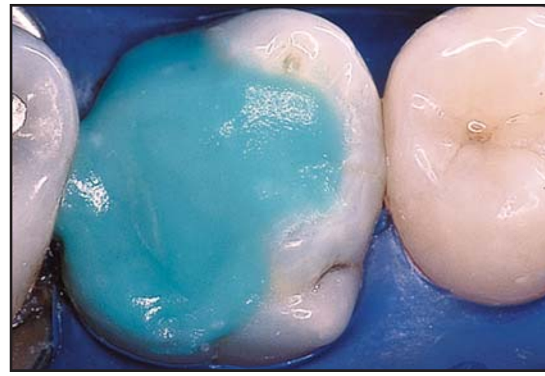

Figure 6. The preparation is cleaned with 2% chlorhexidine.

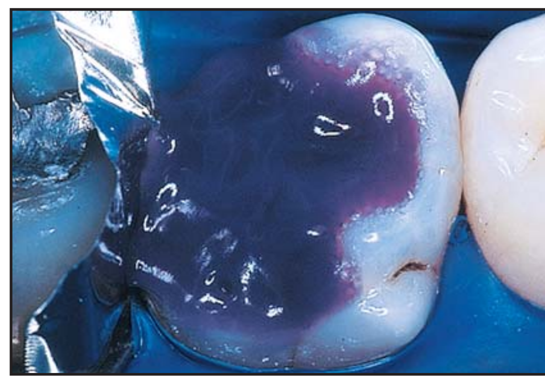

Figure 7. The preparation is etched for 15 seconds with 37.5% phosphoric acid semigel.

cement.[10] The restoration was polymerized from all aspects for 60 seconds, and residual cement at the gingival margin was removed with a scalpel.

The interproximal region was finished with #12 and #30 fluted, needle-shaped finishing burs, and the occlusal anatomy was refined with 12- and 30-fluted, egg-shaped finishing burs (Figure 9A). A composite surface sealant was applied and cured to seal any cracks or microscopic porosities that may have formed during finishing (Figure 9B). Initial polishing of the occlusal surface was accomplished with rubber points. Finally, the restoration was polished with aluminum oxide paste and a synthetic foam cup. The proximal surface was smoothed with polishing paste and aluminum oxide finishing strips. The rubber dam was removed and the patient was asked to first perform closure without force and then centric, protrusive, and lateral excursions. Any necessary equilibration was accomplished, and the final polishing was repeated. The contacts were tested with unwaxed floss and the margins were inspected. Final inspection of the completed restoration revealed a harmonious integration of laboratory-processed composite resin with the existing tooth structure (Figure 10).

System Components

The composite resin utilized in this case (ie, belleGlass NG, Kerr/Sybron, Orange, CA) contains a combination of two different materials: an "artificial dentin" (base composite) and an "artificial enamel" (surface composite). The filler particles are silanated to promote adhesion to the organic matrix. The filler composition varies for the dentin and the enamel. The artificial dentin utilizes barium aluminosilicate glass fillers of different sizes in the opacious dentin and dentin materials (87% by weight, 72% by volume in the opacious dentin; 78% by weight, 63% by volume in the translucent dentin), which provide durable mechanical properties with a low coefficient of thermal expansion. The fillers used in the translucent dentins and enamels consist of microhybrid particles (0.4 μm in size [67%]) and silica nanoparticles (50 nm in size [33%]), that improve surface properties such as polishability, clinical surface gloss, and wear resistance. The artificial enamel utilizes borosilicate glass filler and silica nanoparticles (77% total filler by weight; 70% by volume) that provides wear resistance and excellent optical properties by enhancing the translucency and opalescence of the composite.[11,12]

Additionally, the matrices for the dentin and enamel differ. The dentin matrix utilizes a regular bis-GMA resin, while the enamel matrix is a combination of aliphatic and urethane dimethacrylate resins. The different matrices determine the physical properties of the artificial dentin and the artificial enamel, giving each the necessary characteristics for optimal use. Because they differ, however, the layering of the composite may require additional blending while shaping and light curing.[13]

The polymerization process combines two different curing systems. The artificial dentin is initially cured by

Figure 8. An adhesive agent (ie, Optibond Solo Plus and activator, Kerr/Sybron, Orange, CA) is applied, air thinned, and then light cured for 20 seconds.

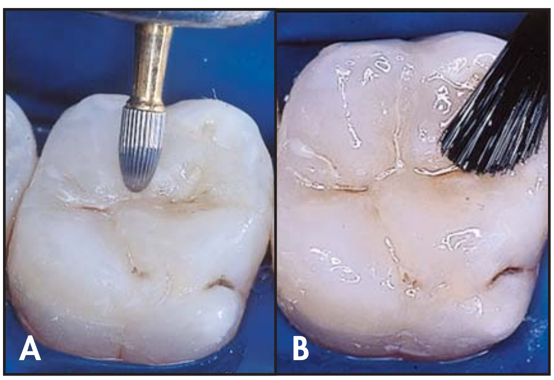

Figure 9A. Occlusal anatomy is refined with fluted egg-shaped finishing burs. 9B. A composite surface sealant was applied after finishing was completed.

a conventional curing light, which stabilizes the restoration during buildup and preserves unreactive sites to enhance bonding. The enamel and dentin are then cured in a proprietary oven at a temperature of 135°C and a pressure of 60 psi in a nitrogen atmosphere. The elevated temperature and nitrogen gas increase the polymer conversion, and the pressure allows the oxygen to be purged out of the system in cycles. This is beneficial since oxygen limits the degree of polymerization by competing at the carbon double-bond sites. Therefore, replacing oxygen with nitrogen allows for a more complete cure since no air-inhibited layer remains uncured.[14] Study results indicate that a conversion rate of 98.5% polymerization (Differential Scanning Calorimeter method) may be achieved with this material with a 20-minute curing period.[15] The enamel layer is designed to improve wear resistance through the heat/pressure polymerization process. The dentin layer has been matched to the coefficient of thermal expansion of a natural tooth and the flexural strength and modulus of natural dentin, and the polymerization shrinkage

Figure 10. Postoperative view reveals the integration of the onlay with the existing tooth structure. Note the marginal adaptation of the indirect composite restoration.

is reduced to 0.9% by volume. The resulting composite material provides maximum strength and homogeneity, aesthetics, color stability, and enhanced resistance to wear and deformation.[10]

While it is possible to use a variety of indirect resin systems (eg, Tescera ATL, Bisco, Schaumburg, IL; Sculpture Plus, Jeneric/Pentron, Wallingford, CT; Gradia Light-Cure, GC America, Alsip, IL) to fabricate an inlay or onlay similar to the one featured herein, these partial-coverage restorations can also be fabricated of porcelain. Factors for determining favorable clinical case selection of porcelain or processed composite resin inlays or onlays include:

- **Polishability**—Since occlusion is equilibrated after cementation, the processed composite resin offers an advantage over porcelain because of its ability to be polished intraorally. It is more difficult to establish a highly polished surface intraorally on porcelain after the glaze has been removed.[16] This unpolished surface has been shown to increase wear of the opposing dentition.[3]
- **Properties**—Porcelain is not as elastic as processed composite resin, and therefore does not tolerate elastic deformation.[17] This can result in fracture of the ceramic margins at try-in. Porcelain has a high resistance to compression and has a low resistance to flexion and traction, and hence is fragile when subjected to tensile stresses.[18] This presents a challenge for some inlay preparations, as not all preparations provide the compression required for the ceramic material. The flexural strength of second-generation composite resin is in the range of 120 MPa to 150 MPa, which is higher than that of feldspathic ceramic (65 MPa). This slight elasticity of the composite resin helps to absorb some of the strains and thereby protects the adhesive bond at the tooth-restorative interface.[17]

- **Wear compatibility**—Porcelain is harder than tooth structure and when not managed properly has the potential to abrade natural teeth at an accelerated rate, whereas second-generation composite resins are softer and have a more favorable wear compatibility with the opposing natural dentition.[16]
- **Cavosurface margins**—Porcelain restorations have the potential for microgaps at the tooth restorative interface; second-generation composite restorations can be made with relatively small gaps. These cavosurface margins are a weak point of the ceramic restoration.[16]
- **Chairside modifications**—Porcelain modifications (eg, contacts, fractured margins) cannot be restored at chairside, whereas indirect resin restorations can be modified chairside.[19]
- **Impact absorption**—Composite materials have shown a greater capacity to absorb compressive loading forces and reduce the impact forces by 57% more than porcelain. Therefore, composites transmit less of the applied load to the underlying tooth structure.[20]
- **Thermal expansion**—Composite inlays have excellent marginal integrity because of the similar thermal expansion rate as the luting cement. Conversely, the variation in coefficients of thermal expansion for porcelain inlays and the composite luting cement can result in an increased width of luting gap.[21]

Although laboratory-processed composite resins provide important clinical advantages in many situations, there are several factors that should be considered for the use of intracoronal porcelain restorations. Those factors include the efficiency and ease of fabrication in the laboratory as a result of advanced technology (eg, injectable ceramics and CAD/CAM systems), the availability of these systems in laboratories, and the technician's familiarity with this technology. Composite systems for CAD/CAM technology are not as common. In addition, porcelain systems are unsurpassed in stability of color, gloss, and wear resistance. These indirect restorative systems complement and broaden the scope of alternative restorative modalities that are available to assist the patient, technician, and dentist in making an informed selection for different clinical situations.[17]

Conclusion

Laboratory-fabricated resin restorations are not designed to *replace* other therapeutic modalities but to *supplement* the services that are offered to dental patients. The primary advantages of the indirect resin inlays and onlays are conservation of tooth structure, tooth reinforcement, and aesthetics. As requests for aesthetic nonmetallic restorations in the posterior region continue to increase, contemporary indirect composite resins will complement other restorative alternatives for the discriminating patient and clinician. As with most restorative procedures, however, the final result is based on the experience and judgment of the clinician and technician in creating a form that follows function and the imagination and artistry to ensure that the anatomical form defines color.

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Continuing Education (CE) Exercise No. X

X
CONTINUING EDUCATION

To submit your CE Exercise answers, please use the answer sheet found within the CE Editorial Section of this issue and complete as follows: 1) Identify the article; 2) Place an X in the appropriate box for each question of each exercise; 3) Clip answer sheet from the page and mail it to the CE Department at Montage Media Corporation. For further instructions, please refer to the CE Editorial Section.

The 10 multiple-choice questions for this Continuing Education (CE) exercise are based on the article, "Developing form, function, and natural aesthetics with laboratory-processed composite resin—Part II," by Douglas A. Terry, DDS, Karl F. Leinfelder, DDS, MS, and Chuck Maragos, CDT. This article is on pages ###-###.

1. The internal characterization of tint within the final artificial dentin layer provides the following:
a. A three-dimensional effect.
b. Emphasizes form.
c. Internal color.
d. All of the above.

2. The polymer conversion with this indirect system can be increased by the following:
a. Elevated temperature.
b. Nitrogen gas.
c. H_2O.
d. Both a and b.

3. A properly finished, indirect composite restoration can provide the following benefits:
a. Aesthetics.
b. Longevity.
c. Wear resistance.
d. All of the above.

4. In the adhesive surface preparation of this indirect composite resin restoration, the silane acts as a coupling agent between the filler particles on the indirect resin surface and the resin cement. The mechanism of action enabled silicate particles to become embedded in the surface of the restoration during sandblasting which then reacted with the silane to improve the bond strength.
a. The first statement is correct and the second statement is incorrect.
b. The first statement is incorrect and the second statement is correct.
c. Both statements are correct.
d. Both statements are incorrect.

5. The filler composition for this indirect resin system is the same for the dentin and the enamel. The artificial dentin utilizes glass fillers of different sizes and composition in the opacious dentin and dentin materials which provide durable mechanical properties with a low coefficient of thermal expansion.
a. The first statement is correct and the second statement is incorrect.
b. The first statement is incorrect and the second statement is correct.
c. Both statements are correct.
d. Both statements are incorrect.

6. The indirect composite resin system utilized to fabricate this restoration contains a combination of two different composite materials which are:
a. Cervical and base composite.
b. Surface and base composite.
c. Cervical and surface composite.
d. None of the above.

7. The filler particles used for the translucent dentin and enamels for this indirect system provide the following characteristics:
a. Improved surface gloss.
b. Enhanced surface polishability.
c. Increased wear resistance.
d. All of the above.

8. Purging oxygen out of the system in cycles and replacing with nitrogen provides the following:
a. Eliminates the air-inhibition layer.
b. Reduces microleakage.
c. Allows for a more complete polymerization.
d. Both a and c.
e. All of the above.

9. Composite materials have shown a greater capacity to absorb compressive loading forces and reduce the impact forces by 57% more than porcelain. Composites transmit less of the applied load to the underlying tooth structure.
a. The first statement is correct and the second statement is incorrect.
b. The first statement is incorrect and the second statement is correct.
c. Both statements are correct.
d. Both statements are incorrect.

10. Composite inlays have excellent marginal integrity because of the similar thermal expansion rate as the luting cement. The similarity in coefficients of thermal expansion for porcelain inlays and the composite luting cement can result in an increased width of luting gap.
a. The first statement is correct and the second statement is incorrect.
b. The first statement is incorrect and the second statement is correct.
c. Both statements are correct.
d. Both statements are incorrect.