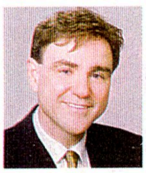
# Optical Integration With Indirect Posterior Composite Resins: The Natural Inlay

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The placement of prefabricated ceramic inlays as esthetic obturations was described as early as 1856.[1,2] In 1882, Herbst developed a fired ceramic inlay,[3] before the use of amalgam in 1895. A technique for fabricating fired ceramic inlays over platinum foil was developed by Land in 1888.[1,4] However, these restorations were abandoned until the last decade because of clinical shortcomings such as restoration fractures, cement failures, and interfacial leakage.[5,6] Conventional restorative dentistry previously relied on the use of amalgams and gold inlays to recreate form and function for intracoronal restorations of posterior teeth. However, esthetic restorative dentistry focuses on achieving restorations of beautiful natural-looking teeth that will maintain function and structural integrity, while eliminating the appearance of metal.

Recent innovations in adhesive systems and procedures, technology, and restorative materials have resulted in the use of bonded restorative materials to reestablish function, shape and contour, color (hue, value, and chroma), and natural light transmission, as well as to recapture strength and esthetics through conservative adhesive tooth preparation. From the wide range of restorative materials, laboratory-processed fiber-reinforced composite resin and porcelain represent two esthetic alternatives for modern posterior restorations. Laboratory-processed inlays fabricated with porcelain or composite resin provide esthetic results that may also reinforce tooth structure. Because this adhesive procedure strengthens the cusps and provides additional support for the dentition, a more conservative preparation design can be used. Additionally, these two systems provide precise marginal integrity, ideal proximal contacts, wear resistance similar to tooth structure, excellent anatomical morphology, and optimal esthetics.[7,8] Since both of these restorative systems can provide predictable clinical results, a comparison of the attributes and capabilities of porcelain vs processed composites will allow for proper case selection by the patient, technician, and restorative dentist.

## FACTORS FOR SELECTION OF RESTORATIVE MATERIALS

Factors for determining favorable clinical case selection of porcelain or processed composite resin include:

*Intraoral polishability*—Because occlusion is equilibrated after cementation, the processed composite resin offers an advantage over porcelain or castable porcelain because of the ease of intraoral polishability. It is more difficult to establish a highly polished surface intraorally on porcelain after the glaze has been removed. This unpolished surface has been shown to increase wear of the opposing dentition.[9,10]

*Properties*—Porcelain is stiff, but brittle and not as elastic as processed composite resin, and therefore does not tolerate any elastic deformation. 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[11] and is therefore fragile when subjected to tensile stresses. This presents a challenge for some inlay preparations because not all preparations provide the compression required for the ceramic restorative material. The flexural strength of second-generation composite resin falls 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 absorb some of the strains and therefore protects the adhesive bond at the tooth-restorative interface.[8]

*Wear compatibility*—Porcelain is harder than tooth structure and has the ability to abrade natural teeth at an accelerated rate, whereas second-generation composite resins are softer and have a more favorable wear com-

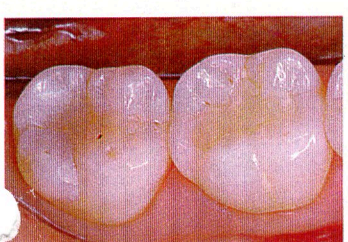


*Figure 1—Preoperative occlusal view of defective composite restorations with recurrent decay.*

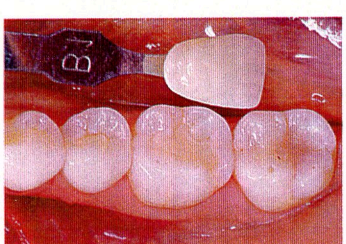



*Figure 2—Shade selection was performed before rubber dam placement.*

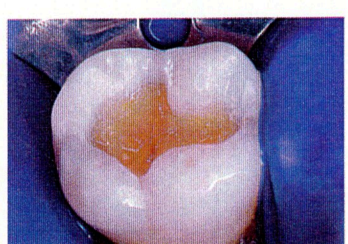


*Figure 3—Completed preparation design.*

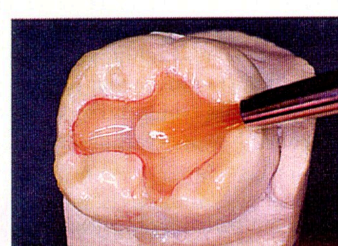
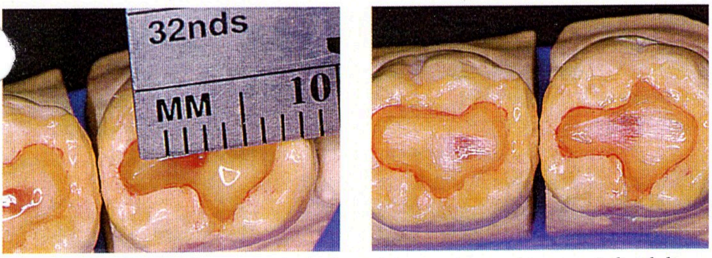


*Figure 4—A B-1 shaded flowable composite was injected and uniformly distributed with a camel hair brush.*




*Figures 5A and 5B—The preparation's dimension was measured in a mesiodistal direction for the placement of the bundle of glass fibers.*

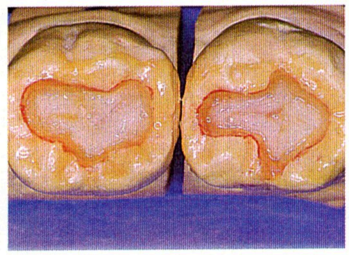


*Figure 6—A B-1 shaded composite was placed as the initial "artificial dentin" layer in the center of the preparation and an indentation was created around this central artificial dentin core.*

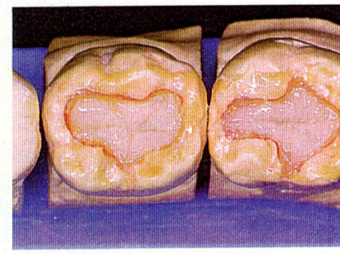


*Figure 7—The first enamel layer, a white shaded composite (Neutral), was applied over the occlusal surface and into the indentation to form a wedge.*

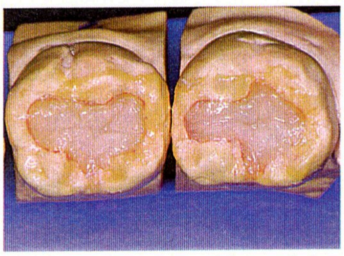
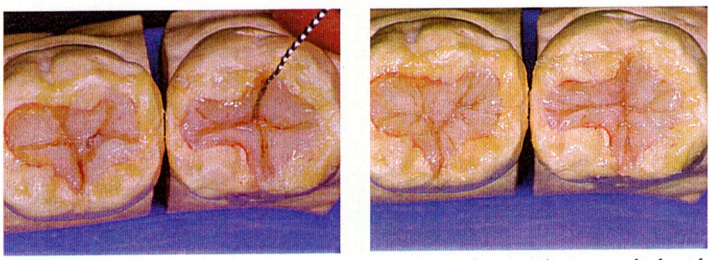


*Figure 8—A final enamel layer of clear composite (Super Clear) was applied at the cavo-surface margin and smoothed into the existing anatomical morphology.*



*Figures 9A and 9B—A brown tinted resin (Brown Color Paste) was applied with an endodontic file in the previously formed invagination. The layers were compressed together, creating a fine line of stain from the base of the invagination to the occlusal surface.*

patibility with the opposing natural dentition.[12,13]

*Cavo-surface margins*—Porcelain margins have larger gaps at the tooth-restorative interface, whereas second-generation composite restorations can be made with smaller gaps. These cavo-surface margins are a weak point of the ceramic restoration.[12]

*Chairside modifications*—Porcelain modifications (eg, contacts, fractured margins) cannot be restored at chairside, whereas second-generation composites can be.[14-16]

*Monochromatic vs polychromatic*—Injectable ceramics are monochromatic and color can be altered with external stains, which can be removed with occlusal adjustment or occlusal wear. Second-generation composite resins can be internally layered for a polychromatic effect.

*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, composite transmits less of the applied load to the underlying tooth structure.[17]

*Thermal expansion*—Composite inlays share similar thermal expansion rates with inlays and luting cement. This similarity provides an advantage over the unmatched coefficients of thermal expansion in porcelain inlays and their composite luting cements, as such unmatched coefficients can result in an increased potential for a microgap.[18]

These 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.[8]

Second-generation indirect systems, also referred to as "ceromers" (ceramic optimized polymers), polymer ceramics, and polymer glass, maintain a higher density of inorganic ceramic microfillers compared to the earlier-generation direct and indirect systems.[19] Ceromers have been noted for providing the advantages of composite resins and porcelain, without being confined by their inherent limitations.[20]

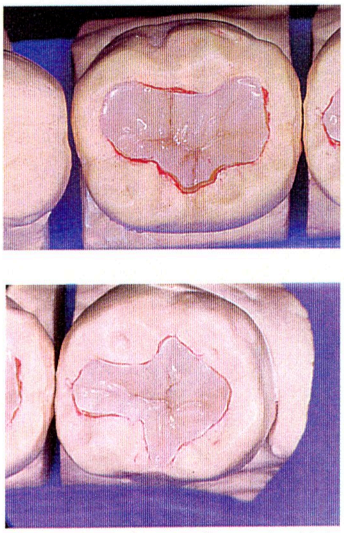
*Laboratory-processed inlays fabricated with porcelain or composite resin provide esthetic results that may also reinforce tooth structure.*

## Second-Generation Indirect Systems

The biomaterials, known as "microhybrids," include a combination of inorganic particles (fillers) and an organic polymer (matrix), with a filler content that contains twice the organic matrix content (approximately 66% inorganic fillers and 33% resin matrix). The filler is the primary determinant of the clinical and physiochemical properties of composite resin. These submicron-particle fillers demonstrate exceptional surface characteristics, such as polishability and wear resistance.[21] The wear is influenced by the filler size, shape, load, and matrix bonding.[22] In fact, a significant reduction in wear resistance has been reflected by decreasing the size of the filler particle.[22,23]

More recent formulations, such as **Sculpture®/FibreKor® (Pentron Laboratory Technologies)**, with unique resin and filler chemistry, increased filler volume, and decreased particle size, seem to exhibit greater wear resistance. Newer formulations in size, shape, composition, and concentration have significantly enhanced the mechanical characteristics of second-generation composite resins by reducing the polymerization shrinkage, while increasing the flexural and tensile strength, the resistance to abrasion and fracture, and color stability.[24]

In addition, the various combinations of light, heat, pressure, vacuum, and the use of nitrogen to enhance the degree of conversion through postcuring continue to improve the physical and mechanical properties of second-generation indirect resin systems. The curing process eliminates residual monomers and ensures a uniform cure with an optimum level of polymerization. The elimination of oxygen with pressure, vacuum, or nitrogen removes the entrapped pockets that contribute to the opacity of the restorative material and stain resistance. The authors' use of these restorative materials has indicated improved optical properties with enhanced translucency, fluorescence, and opalescence similar to tooth structure. Several of the second-generation indirect resin composite systems that also include these characteristics are: **belleGlass™ HP (Kerr Corp.)**, **Artglass® (Heraeus Kulzer, Inc.)**, **Cristo-**



Figures 10A and 10B—*The completed laboratory result reveals the enhanced optical characteristics and the anatomical morphological detail that can be achieved with second-generation indirect resin systems.*

Figure 11—*The preparation was cleaned with 2% chlorhexidine.*

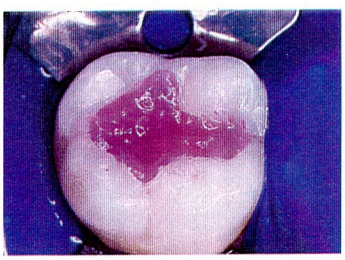


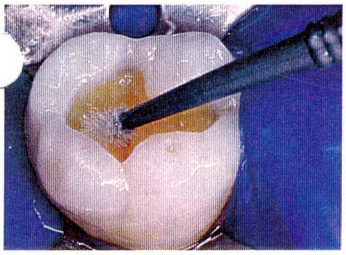
Figure 12—*The preparation was etched for 15 seconds with 37.5% phosphoric acid semi-gel.*

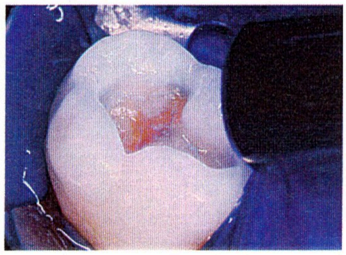
bal® (DENTSPLY®/Ceramco), and Targis®/Vectris® (Ivoclar Vivadent, Inc.).

The various methods of postcuring allow for secondary curing of the composite by increasing the conversion of the material from monomer to polymer.[24] This heightened but controlled degree of polymerization increases fracture toughness, flexural and diametral tensile strength, wear resistance, incisal edge strength[25] and color stability.[26]

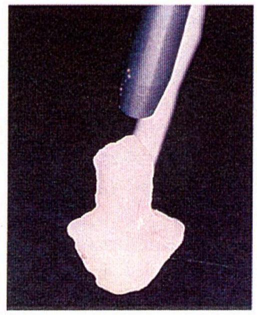
Accepted clinical applications for these restorative polymers include fixed prosthodontic restorations such as telescopic and conical crowns, implant-supported restorations, progressive loading of implant-supported prostheses, precision attachments, inlays, onlays, crowns, long-term provisional restorations, laminated veneers, metal-reinforced crowns and bridges, fiber-reinforced bonded bridges, and fiber-reinforced crowns and bridges.[8]

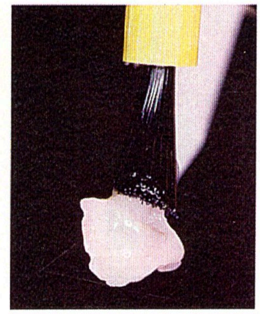
This article describes the specific material properties of second-generation composite restorative materials. A detailed review of the laboratory and clinical reconstructive phase, including preparation design and fabrication (wedge technique and fiber-reinforcement), is presented. Adhesive surface preparation and cementation protocol demonstrate the clinical application of a laboratory-processed, indirect system that uses light, heat, and vacuum in conjunction with nitrogen pressure to fabricate inlay restorations on the mandibular right first and second molars.





Figures 13A and 13B—A single-component adhesive was applied, lightly air-dried, and light-cured.





*Figures 14A and 14B—The internal surface of the composite restoration was microetched followed by a silane application.*

## Components of the System

The specific indirect composite resin used in this case comprises a resin material and a curing mechanism. Sculpture® contains a combination of two different materials: an "artificial dentin" (base composite) and an "artificial enamel" (surface composite). The filler particles are silanated for improved adhesion to the organic matrix. The filler composition varies for the dentin and the enamel. The "artificial dentin" (opacious body and body) uses a blend of bariumborosilicate glass and colloidal silica fillers of different sizes in the opacious and translucent dentin materials that provide durable mechanical properties with a low retraction (friction) coefficient. The "artificial enamel" (incisal) incorporates borosilicate glass fillers and colloidal silica glass fillers that provide wear resistance and excellent optical properties by enhancing the translucency and opalescence of the composite.

The matrices for the dentin and enamel also differ. The dentin matrix uses a blend of PCDMA resin and ethoxylated bisphenol-A-dimethacrylate resin, while the enamel matrix is a blend similar to that of the dentin matrix, diluted with small amounts of triethyleneglycoldimethycrylate (TEGDMA). The refractive indexes of the resin matrix and fillers are controlled to alter the translucency/opacity of the materials. The dentin and incisal materials have refractive indexes close to that of the tooth structure (1.5 to 1.52). The differing matrices determine the physical properties of the "artificial dentin" and the "artificial enamel," giving each necessary and required characteristics for optimal use.

The polymerization process combines two different curing systems. The "artificial dentin" is initially cured by a conventional curing light with or without pressure, which stabilizes the restoration during build-up and preserves unreactive sites to enhance bonding. The enamel surface of the restoration is glazed by means of light-curing in a pressure vessel under a pressure of 80 psi in a nitrogen atmosphere. The elevated pressure and nitrogen gas allows the oxygen to be purged out of the system in cycles. This is beneficial, as 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, as no air-inhibited layer remains uncured.[27] The final curing in the heat curing unit (Sculpture® curing oven) under vacuum increases the polymer conversion and eliminates the residual monomers. The resulting composite material provides increased strength and homogeneity, excellent esthetics with enhanced optical properties and fluorescence, low water sorption and solubility, color stability, and superior resistance to wear and deformation.[7]

The FibreKor® fibers are unidirectional glass fibers that are preimpregnated with resin. Unlike the fiber-reinforcing materials containing woven glass fiber or polyethylene fibers, the FibreKor® system uses an advanced silanation and preimpregnated technology to allow the resin to surround and penetrate each glass filament to create a bonded cohesive bundle of fibers. The resin used to preimpregnate the glass fibers contains the same methacrylate functional group as the Sculpture® resin matrix, which is responsible for the excellent chemical bond between the two materials through polymerization. FibreKor® has a rupture modulus of approximately 1,000 MPa, which provides a high flexural strength when used as a framework. These fibers are available in five different translucent shades in strips and bars of predetermined dimensions and can be used to form the reinforcing network for restorations. The FibreKor® material is visible light- and heat-curable and is quite adaptable before polymerization, allowing for ease of placement on working dies during fabrication of the framework.

*Replacing oxygen with nitrogen allows for a more complete cure.*

## Case Study

A 34-year old woman presented with defective composite resin restorations in the mandibular right first and second molars. The existing composite restorations had open margins with recurrent decay (Figure 1). After thorough examination and assessment, the patient expressed interest in replacement of the existing composite restorations with more durable tooth-colored restorations.

### Reconstructive Phase—Clinical Preparation

The following clinical protocol employs the indirect restorative technique requiring two appointments. At the first appointment, a shade selection and photograph comparison were performed before treatment because an elevated value and/or the selection of an improper shade could result from selecting the shade after tooth dehydration (Figure 2). Upon removal of the existing composite restorations and recurrent caries, the cavity design followed the preparation guidelines for indirect inlay restorations, including: all enamel supported by sound dentin; all internal angles and edges rounded; isthmus width at least 2 mm with a depth of at least 1.5 mm; all proximal walls flared or diverged 5 to 15 degrees with no undercuts; and sharp cavo-surface margins and the gingival margins prepared to a 90-degree cavosurface line angle (butt joint) with no feather-edge preparation (Figure 3).[7,13,20,24] As a general guide, when the isthmus preparation exceeds half of the distance from the central fossa to the cusp tip, cuspal coverage should be considered. In areas of low stress and where there is minimal potential of tooth flexure, thinner areas of tooth structure may be judiciously inlayed. For large restorations or weak teeth with minimal enamel, fibers should be included as a base on which to veneer the composite.[20]

Before taking the impression, it is important to seal the dentin tubules with a hybrid layer.[28,29] This protects the pulp from the invasion of microorganisms and reduces sensitivity during the provisional stage. The preparation was etched for 15 seconds with 37.5% phosphoric acid semi-gel (**Gel Etchant, Kerr Corp.**), rinsed for 5 seconds, and lightly air-dried to avoid dessication. A thin layer of single-component adhe-

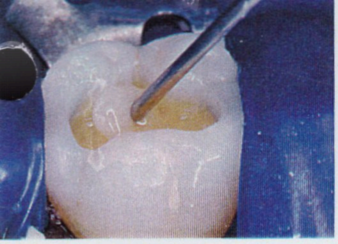


Figure 15—The resin cement was injected into the preparation.

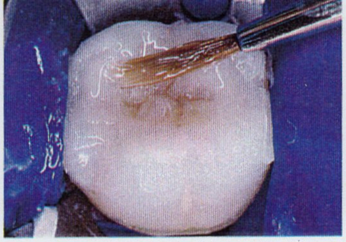


Figure 16—The residual resin cement was removed from tooth No. 30 with a sable brush.

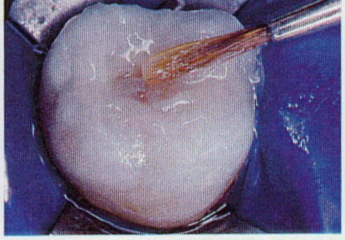


Figure 17—A sable brush was used to remove the remaining resin cement from tooth No. 31.

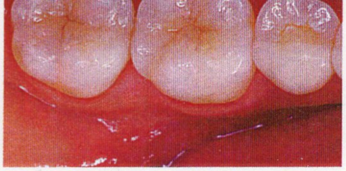
Figure 18—After polymerization, an excess resin cement was removed with scalpel blade.



sive (**OptiBond™ Solo Plus, Ker Corp.**) was applied on the prepa ration surfaces with an applica tor for 20 seconds, air-thinne for 5 seconds, and light-cured fo 20 seconds. An accurate viny polysiloxane impression (eg **Aquasil™, DENTSPLY®/ Caulk Imprint™ II and Position® Pent Quick, 3M ESPE; Splash! Discus Dental; Take 1, Ker Corp.**) was taken defining a cavo-surface margins. A model o the opposing dentition and a interarch occlusal bite registra tion was conveyed with 35-mm photographs of the shade ta comparison. A direct provisiona restoration was placed with matrix band (**Automatrix® DENTSPLY®/Caulk**) using light-cured semiflexible materia (**Fermit®/Fermit®-N, Ivocla Vivadent, Inc.**) and the occlu sion was inspected.

## Laboratory Fabrication

The technician needs mor than the stone model to fabricat an esthetic restoration that repli cates the colors, texture, shape contour, and anatomical mor phology of the existing tooth. A shade diagram describing th transition of color from fossa t cavo-surface margin, margina ridge translucency, occlusal wea facets, and occlusal-groove stain ing becomes the technician restorative recipe. To convey th color of the enamel and th dentin, a 35-mm photograph o digital photograph of the shad tab to the preexisting tooth an to the internal cavity preparatio provides valuable informatio for comparison to the technician However, the authors find tha the variances in shade tabs with in the same system necessitat the inclusion of specific shad



*Figures 23A and 23B—The postoperative occlusal view of the definitive restorations. Note the optical integration of composite resin with the existing tooth structure.*

adequate field control. The "total etch" technique was used for its ability to minimize the potential of microleakage and enhance bond strength to dentin and enamel.[32] The preparation was etched for 15 seconds with 37.5% phosphoric acid semi-gel

Once the dentin and the enamel were remoistened with a rewetting agent (**Tubulicid Red, Global Dental Products, Inc.**) on an applicator, a hydrophilic adhesive system was used. The dual-cure composite resin (**Nexus 2™, Kerr Corp.**) was used as a cementation material. A single-component adhesive (OptiBond™ Solo Plus) was applied with an applicator for 20 seconds with continuous motion and lightly air-dried for 5 seconds. The agent was light-cured for 20 seconds (Figures 13A and 13B).

The inner surfaces of the inlay were microetched with **CoJet® Sand (3M ESPE)**, followed by a silane application to restore any coating on the original fillers that may have been removed by sandblasting (Figures 14A and 14B). As a bifunctional molecule, the silane acts as a coupling agent between the filler particles on the indirect resin surface and the resin cement. CoJet®, a tribochemically-assisted bonding system, is designed to create potential micromechanical retention and a chemical bond between composite and most types of restorations.[33] The mechanism of action allows the silicate particles to become embedded in the surface of the restoration during sandblasting, which then reacts with the silane to improve bond strengths.[34] However, it is imperative not to etch or rinse after CoJet® surface treatment, because reports indicate that this can significantly reduce shear bond strengths.[35,36]

After the surface treatment, the restoration was cemented with a dual-cure composite cement (Nexus 2™). The cement was mixed and loaded into a needle tube syringe tip (**Needle Tube, Centrix, Inc.**) and injected into the entire preparation (Figure 15). A blunt tip instrument was used to seat and hold the restoration firmly in place and the excess cement was removed with a sable brush (Figure 16). It is imperative to leave a residual amount of compensate for the polymerization shrinkage of the cement. Initial polymerization should last 20 seconds, while the restoration is held in place with the blunt tip instrument. The residual cement was removed with a sable brush (Figure 17), leaving only a small increment at the margin to counteract any polymerization shrinkage of the cement. A thin application of glycerin was applied to all the margins to prevent the formation of an oxygen inhibition layer on the resin cement.[7] The restoration was polymerized from all aspects: facial, occlusal, lingual, and proximal surfaces, each for 60 seconds.

### Finishing and Polishing

After the resin cement had been polymerized, any excess at the margin was removed with a scalpel blade (**#12 Bard Parker, Becton Dickinson and Company**) (Figure 18). The occlusal anatomy was refined with 12- and 30-fluted egg-shaped finishing burs (**Specialty Carbide Burs, #7406 and 9406, Midwest Dental/DENTSPLY®**) (Figure 19). After the initial finishing procedure, the margins and surface defects were sealed. All accessible margins were etched with a 37.5% phosphoric acid semi-gel, rinsed, and air-dried (Figure 20). A composite surface sealant was applied and cured to seal any cracks or microscopic porosities that may have formed during finishing procedures (Figure 21). The restoration was finally polished with rubber points and composite resin-polishing paste (Figures 22A and 22B). 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 with 12- and 30-fluted egg-shaped finishing burs, and the final polishing was repeated. The contact was tested with unwaxed floss and the margins inspected. The postoperative result demonstrates the optical integration of composite resin with the existing tooth structure (Figures 23A and 23B).

## Conclusion

Modern clinicians have many of the same clinical challenges on selecting the appropriate treatment modality as their colleagues of the 19th century. While new products and technological advances impact our profession positively, a new burden rests on clinicians to continually educate themselves on the properties and applications of the new materials. This article has reviewed the specific material properties of second-generation indirect resin systems and provided a detailed description of the preparation, fabrication, cementation, and finishing of an inlay restoration using a current indirect system, Sculpture®/FibreKor®. In addition, this article has demonstrated that when proper laboratory and clinical techniques are combined with the physical (optical) properties of these new materials, the restorative result can be indistinguishable from natural dentition. However, to achieve these optimal functional and esthetic results, communication and understanding between the technician and the clinician remains essential. Finally, because dentistry is an ever changing and growing field, it is important to remember that no one restorative material is a panacea to all patients or every clinical situation. New restorative materials and accompanying techniques should be used to complement[8] our existing clinical repertoires. ○

## Disclosure

Dr. Terry received an honorarium from Pentron Clinical Technologies for writing this article.

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## Product References

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**Address:** 53 N. Plains Industrial Rd. Wallingford, CT 06492
**Phone:** 800.243.3969
**Fax:** 877.677.7397

**Product:** belleGlass™ HP, Gel Etchant, OptiBond™ Solo Plus, Take 1, Nexus 2™
**Manufacturer:** Kerr Corporation
**Address:** 1717 West Collins Ave. Orange, CA 92867
**Phone:** 800.537.7123
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**Product:** Artglass®
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**Phone:** 800.343.5336
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**Product:** Cristobol®
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**Product:** Splash!
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