Preservation, Conservation, and Restoration of Posterior Tooth Structure With Advanced Biomaterials

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The search continues for the ideal restorative material that has properties similar to tooth structure. Such a system should be resistant to masticatory forces and have not only similar physical and mechanical properties to that of the natural tooth but also a similar appearance to natural dentin and enamel.[1] The longevity of a restoration increases as the mechanical properties more closely approximate those of the enamel and dentin.[2] An ideal restorative material should fulfill the three basic requirements of function, esthetics, and biocompatibility. At present, no restorative satisfactorily fulfills all these prerequisites.[3]

Optimizing the adhesion of restorative biomaterials to the mineralized hard tissues of the tooth is a decisive factor for enhancing the mechanical strength, marginal adaptation, and sealing that appears to improve the reliability and longevity of the adhesive restoration.[4,5] The search for a tooth restorative interface that mimics the natural tooth condition has resulted in an effective micromechanical bond between composite and mineralized tooth structure. The principle advantages of a bonded restoration include: restoration retention, reduction or elimination of marginal microleakage, and reinforcement of remaining tooth structures.[6] This evolution in the development of adhesive dental technology has dramatically changed the way dentistry is practiced in the modern dental office. Modern adhesive restorative materials and techniques have provided dentists with more conservative treatment avenues that preserve tooth structure while improving the longevity and esthetics of the restoration.[5]

Indirect laboratory-processed composite resin systems provide an esthetic alternative for intracoronal posterior restorations. Laboratory-processed inlays/onlays fabricated with composite resin provide esthetic results that may also reinforce tooth structure.[4] Because adhesive procedures strengthen the cusps and provide additional support for the dentition, a more conservative preparation design can be used. Additional clinical benefits include precise marginal integrity, wear resistance similar to enamel, wear compatibility with opposing natural dentition, ideal proximal contacts, excellent anatomic morphology, and optimal esthetics.[4,5]

Whereas many articles have examined the plethora of uses for indirect resin reinforced systems, this article will focus on the inlay restoration employing an indirect resin reinforced system that uses three curing mechanisms—pressure, light, and heat underwater. This article describes each of the system's mechanisms and the specific material properties of this next generation of an indirect composite resin system (TESCERA™ ATL™, BISCO, Inc) including a detailed review of the laboratory and clinical reconstructive phase with preparation design and fabrication (layering technique and fiber reinforcement). Adhesive surface preparation and cementation protocol have been presented to demonstrate the clinical application of this system to fabricate inlay restorations on the maxillary right first molar and second premolar.

System Components

A better understanding of a specific indirect composite resin system requires a discussion of the components of the system: the resin material and the curing mechanism. The indirect composite resin system used in this case, TESCERA™ ATL™, contains a combination of three types of composite material: dentin, body, and incisal components. Other indirect composite resin systems that could have been used include: belleGlass™ NG (Kerr Corporation), Cristobal®+ (DENTSPLY Prosthetics), and GRADIA™ Light-Cured Micro-Ceramic Composite (GC America Inc).

In choosing a resin material, the particle size determines how to best use composite materials.[6] The filler particle size, distribution, and quantity affects the mechanical properties and clinical success of composite resins.[7] The filler particles are silanated for satisfactory adhesion to the organic matrix. The indirect system's filler composition varies for the dentin material and the body and incisal. The dentin material is a highly filled hybrid (85% by weight, 73% by volume) similar to the proprietary mixture of the direct restorative AELITE™ LS (BISCO, Inc). This increased filler loading allows a volumetric shrinkage of 1.5% while maintaining a high flexural strength.[8,9] The body and the incisal material consists of a reinforced microfill (70% by weight) similar to the proprietary mixture of the direct restorative Micronew™ (BISCO, Inc).[8] Added to the nanoparticles is a relatively large reinforcement particle that averages 1 µm compared to the main filler, which is 0.04 µm. The average particle size for this composite is approximately 50 nm (0.05 µm). The presence of these 1-µm reinforcement particles contributes to the strength by acting as a "crack stopper," whereas the increased particle concentration of the microfill particles provides improved clinical performance through an increased polishability, durability of the polish, wear resistance, and fracture resistance.[10]

The matrices for the dentin, body, and incisal material consist of various combinations of diluents: Bis-GMA (bisphenol A-glycidyl methacrylate), urethane dimethacrylate, ethoxylated bis "a" dimethacrylate (DIMA), and TEGDMA (triethylene glycol dimethacrylate). However, the matrix for the incisal differs from that of the

dentin and body in that the incisal uses a low Bis-GMA concentration, whereas the dentin and body materials have a higher concentration. A study of the incisal material by Ferracane and Condon at Oregon Health Sciences University indicates a greater abrasion resistance than other indirect systems tested.[10] The manufacturer suggests that this improved wear resistance of the incisal material is a result of the change in concentration of Bis-GMA.[11]

Polymerization for this system combines light and heat underwater. The artificial dentin is initially pressurized (60 pounds per square inch [psi]) in a light cup before the light-curing cycle is initiated. The initial pressurization eliminates the incorporation of internal voids and bubbles during the incremental build-up process. The light cup contains white reflection beads, which provide support to the working die while reflecting and diffusing light around the chamber and onto the composite surface. During the incremental build-up process, each light-cure cycle requires 2 minutes and stabilizes the restoration. In the authors' experiences, this allows for the placement of subsequent increments without deforming the underlying composite layer.

After the restoration development, the final cure is accomplished in a heat cup with the restoration submerged in water. Any residual free oxygen in the water is removed by adding an oxygen-scavenger agent because oxygen limits the degree of polymerization by competing at the carbon double bond sites. Removing oxygen allows for a more complete cure because no air-inhibited layer remains uncured.[12] The removal of oxygen also may improve the physical and mechanical properties at the surface. The final restorations are cured using an initial full cycle of pressure (60 psi) with light and heat (peak heat of 130°C and decreasing to approximately 90°C before releasing pressure) for 10 to 13 minutes depending on the restoration size and the initial water temperature. The final curing process with heat under pressure increases the polymer conversion and eliminates the residual monomers. The resulting when 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.[4]

Figure 1—Reinforcement materials of different shapes, sizes, and configurations can be used to improve the flexural strength and fracture resistance of the indirect composite restoration.

Figure 2—Preoperative occlusal view of defective composite restorations with recurrent decay.

Fiber Reinforcement

A principal consideration in determining the long-term success of laboratory-fabricated resin inlays is tooth reinforcement. To reinforce the composite resin, additional fibers (TESCERA™ reinforcement material, BISCO, Inc) are integrated into the resin matrix[13,14] during fabrication and before the curing process. Other fibers that could have been used in this case are: Contruct (Kerr Corporation) and GlasSpan® (GlasSpan®, Inc). These fibers have been surface treated to enhance the adhesion to any synthetic restorative material. Although no long-term clinical trials are available to determine the clinical success of these materials, a recent short-term study on 60 single-crown restorations demonstrated no breakage after 1 year.[15,16] The authors believe it is prudent to incorporate the composite reinforced fibers because the flexural strength and fracture resistance of the restoration is increased.[15,17]

Another reinforcing structure for these indirect composite resin systems is the TESCERA™ structural fibrous material (BISCO, Inc), which consists of pre-tensile stressed quartz fibers that are cured into a resin matrix to provide a rigid, strong reinforcing structure. These materials consist of different shapes and configurations (ie, U-bars, barrels, sleeves, and fiber bundles) that have been surface treated to enhance the adhesion to any synthetic restorative material (Figure 1).

Case Study

Preoperative Considerations

A 41-year-old woman presented with defective composite resin restorations in the maxillary right first molar and second premolar. The existing composite restorations had open margins with recurrent decay (Figure 2). After thorough examination and assessment, the patient expressed interest in replacing the existing restorations with the most conservative, durable, and esthetic restorations available. The preoperative considerations included: preoperative models, custom shade selection, a hand-drawn occlusal and shade diagram, and caries assessment using quantitative light-induced fluorescence.

Before establishing the cavosurface boundaries of the preparation design, it was necessary to evaluate the lingual fissure with light-induced fluorescence (DIAGNOdent, KaVo America Corporation). This system relies on fluorescent diagnosis of caries, in which the fluorescent properties of enamel and dentin are altered by mineral loss. This device aids in monitoring or assessing caries and is a useful adjunct to diagnosing fissure caries. The DIAGNOdent scale reading of 11 indicated no caries present but the region was to be monitored in the future.

Clinical Preparation

Before administering anesthesia and rubber dam isolation, the preoperative occlusal stops and excursive guiding planes were recorded with articulation paper and transferred to a hand drawn occlusal diagram, recorded on an intraoral camera or indicated and reviewed on a stone model. This initial registration is valuable in preparation design when considering placement of centric stops beyond or within the restoration and in minimizing finishing procedures.[18] A preoperative selection of composite resins, tints, and modifiers with their shade and orientation is recorded. Shade selection should be accomplished before rubber dam placement to prevent improper color selection as a result of dehydration and elevated values.[19] When teeth dehydrate, air replaces water between the enamel rods, changing the refractive index that makes the enamel appear opaque and white.[20] The use of a color-corrected daylight source of 5,000°K is necessary for proper color registration.[14] A shade map or restorative recipe can be used to diagram the existing colors of the tooth to be prepared and will indicate anatomic morphologic details such as developmental grooves, shape of embrasures, prominences, convexities, facets, angles, plane areas, or any other characteristics that can provide helpful information when reconstructing the tooth surfaces.[19]

The following protocol requires two appointments. At the first appointment, when anesthesia is administered, the treatment site was isolated with a rubber dam. An elongated hole was created to allow placement of the rubber dam over the retainers to achieve ease of placement and removal, to provide an adequate field control, and to protect against contamination.[20,21] After removal of the composite restorations and recurrent caries, the dam was removed and a second photographic comparison to the underlying dentin color was performed before completion of the preparation to reduce the influences of tooth dehydration (Figure 3). The rubber dam was replaced, a final caries assessment was performed with light-induced fluorescence (DIAGNOdent) (Figure 4), and the preparations were refined. The cavity design followed the preparation guidelines for indirect inlay restorations, which includes: 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° with no undercuts, sharp cavosurface margins, and the gingival margins prepared to a 90° cavosurface line angle (butt joint) with no feather-edge preparation.[4,13,15,22,23] As a general guide, when the isthmus preparation exceeds one 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.[14]

DUX DENTAL

NEED NEW SCAN

Before taking the impression, it is important to seal the dentin tubules with a hybrid layer.[5,24,25] This protects the pulp from microorganisms and reduces sensitivity during the provisional stage. The preparation was cleaned with a 2% chlorhexidine digluconate disinfectant (Cavity Cleanser™, BISCO, Inc) and lightly air-dried for 5 seconds. Other disinfectants that could have been used include: Concepsis® (Ultradent Products, Inc) and Pumice Preppies™ (Whip Mix Corporation). A self-priming etchant (TYRIAN™ SPE, BISCO, Inc) was applied to the entire cavity surface with an applicator tip in 2 separate coats, slightly agitated for 10 seconds, and blotted dry with a foam pellet. A thin layer of single component adhesive (ONE-STEP® PLUS, BISCO, Inc) was applied onto the primed surface with an applicator tip in 2 separate coats, air dried for 10 seconds, and light-cured for 10 seconds per surface (Figure 5). An accurate polyvinylsiloxane impression (TAKE 1®, Kerr Corporation) was taken defining all cavosurface margins. Other impression materials that could have been used include: Aquasil™ (Dentsply Caulk), Imprint™ II or Position™ Penta™ Quick (3M ESPE), and Splash!® (Discus Dental®, Inc). A direct provisional restoration was placed with a matrix band (AutoMatrix®, Dentsply Caulk) using a light-cured, semi-flexible material (Fermit/Fermit N, Ivoclar Vivadent®, Inc) and the occlusion was inspected. The laboratory narrative included a comprehensive description of the patient and her expectations with the preoperative models, a hand drawn shade and occlusal mapping diagram, a model of the opposing dentition, an interarch occlusal bite registration, preoperative photographs, photographs of the preparations with the corresponding custom shade tab for comparison, and an accurate final impression of the preparations.

Figure 3—Photographic custom shade comparison to the natural tooth structure.

Figure 4—Caries detection was performed with light-induced fluorescence.

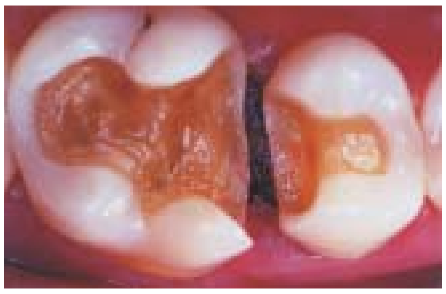

Figure 5—Hybridization of the inlay preparations before impression taking.

Laboratory Fabrication

The technician needs more than the stone model to fabricate an esthetic restoration that replicates the colors, texture, shape, contour, and anatomic morphology of the existing tooth. A shade diagram describing the transition of color from fossa to


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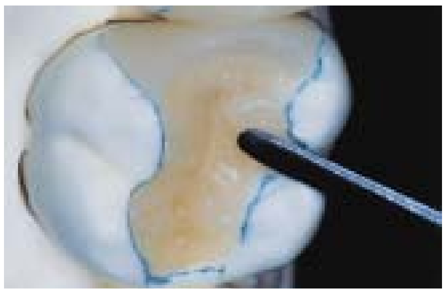


Figure 6—Development of the inner core of the restoration with a body B-2 shaded composite resin.

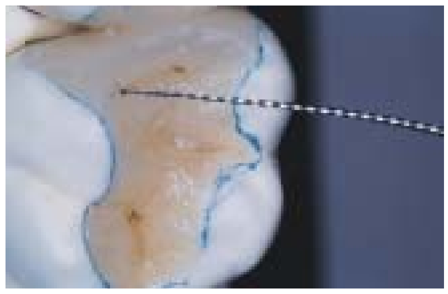


Figure 7—A small amount of red/brown tint was applied to specific areas on the occlusal to give the illusion of fissure stains.

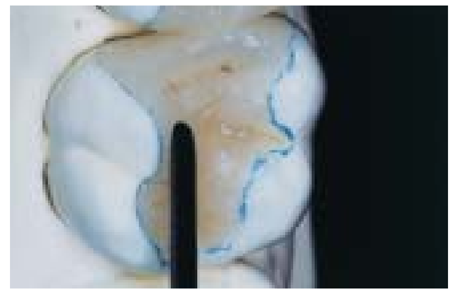


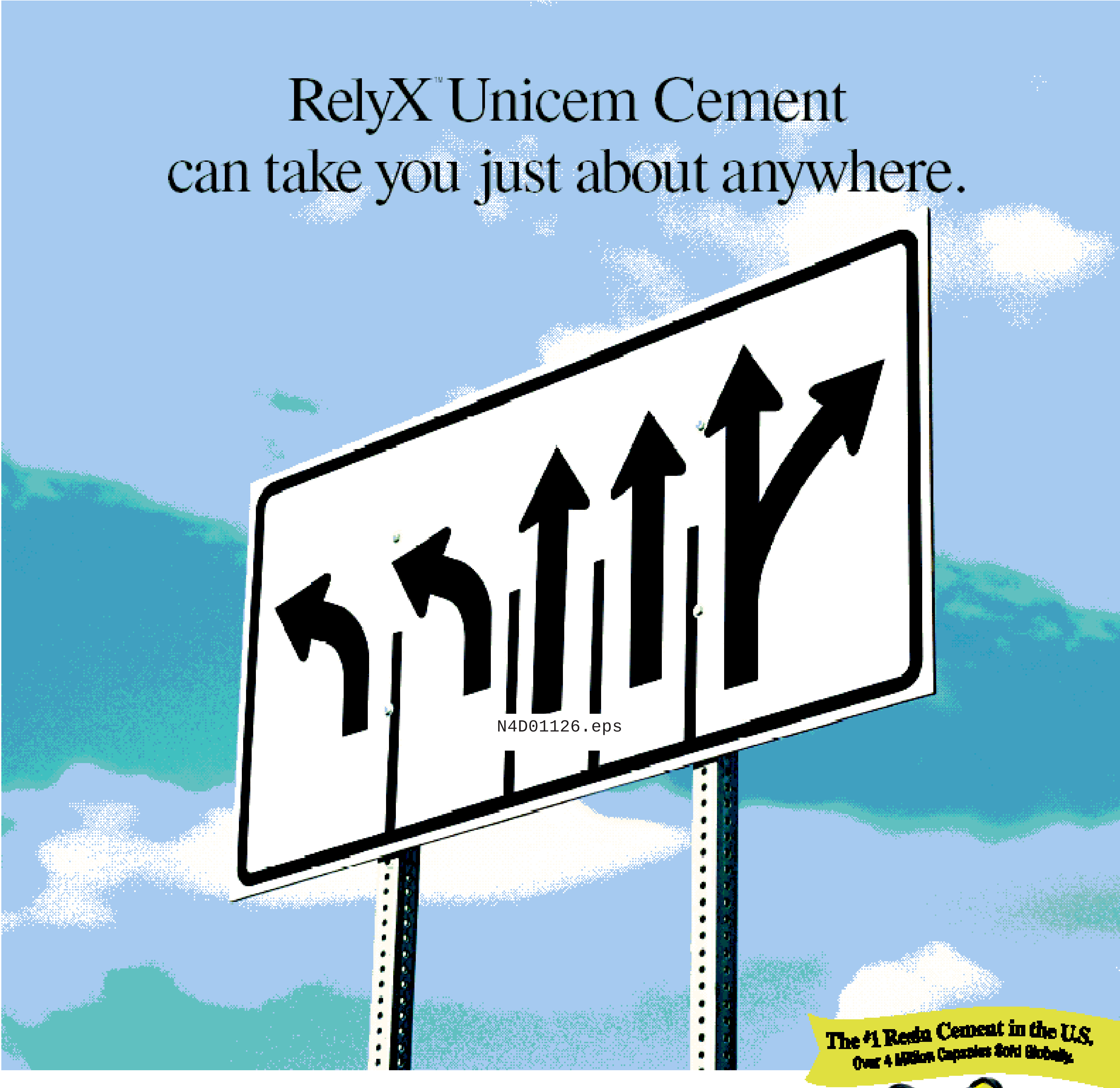
Figure 8—A final occlusal layer (incisal clear) was applied at the cavosurface margin and smoothed into the existing anatomic morphology.

cavosurface margin, marginal ridge translucency, occlusal wear facets, and occlusal-groove staining becomes the technician's restorative recipe. To convey the color of the enamel and the dentin, a 35-mm photograph of the shade tab next to the preexisting tooth and the internal cavity preparation provides valuable information to the technician. Digital photography provides another method for instant transmission of information from the dentist to the laboratory via the Internet. However, the authors find that the variances in shade tabs within the same system necessitate the inclusion of specific shade tabs for the technician so that an exact visual reference can be used during the fabrication of the restoration.[14] Although the shade tab is a pivotal reference point between the dentist and the technician, it is limited by its ability to match all natural teeth.[25] Variations in the color of enamel are related to such factors as opalescent level, value, translucency, and opacity. While the selection of the dentin color is relatively simple, the matching of the enamel where there is integration of tooth structure with restorative material requires a comprehensive understanding of restorative materials, internal shade modifications, tooth morphology, occlusion, and color. The following laboratory procedure describes how this interpretation can be used with laboratory-processed composite resins to integrate the existing color of the natural tooth with the optical properties of the restorative material.

On review of the laboratory narrative, a die stone is mixed with the correct powder to liquid ratio under vacuum and the impression is poured for a master cast and a working cast. The casts are mounted on an articulator for the duplication of occlusal movements. The working model is mounted on dies to facilitate the layering process. After blocking out any undercuts in the preparation, a thin layer of die hardener is applied to the cavity and air-dried; then a separator is applied and air-dried.

As an initial step in the build-up procedure, 1 mm to 2 mm of dentin B-3 shaded composite is placed on the pulpal floor of the die as the initial artificial dentin layer. The preparation's dimension is measured in a mesio-distal direction for the placement of reinforcement fibers. These fibers are internally adapted to the initial layer. Each composite layer is pressurized (60 psi) in a light cup and light-cured for 2 minutes. This addition of fibers significantly increases the flexural strength and fracture resistance of the restoration.[15,17] A B-2 shaded body composite is developed in increments to create an internal dentin core with each subsequent layer cured in the light cup for 2 minutes (Figure 6). An incisal clear shaded composite is applied over the occlusal surface to create a harmonious integration of the tooth enamel with the restorative material. While the material is still soft, the internal characteristics (creation of pits and fissures, staining of grooves, or creation of internal color) were applied using an endodontic file. A mixture of orange tint with a small amount of red/brown tint was applied in a previously formed invagination, according to the preoperative photographs and shade diagram. The serrations of a clean endodontic file are used to enfold and compress the layers together causing a narrowing of the invagination. This allows the stain to migrate to the occlusal, creating a fine line of stain from the base of the invagination to the occlusal surface. The surface is then cured in the light cup for 2 minutes. This allows for intraoral occlusal adjustment without losing internal characterization. To create the illusion of occlusal fissure, a small amount of red/brown tint was applied according to the preoperative photographs and shade diagram and cured in the light cup for 2 minutes (Figure 7). A final enamel of incisal clear composite was applied at the cavosurface margin and smoothed into the existing anatomic morphology (Figure 8).

After the final light-cure cycle, the restorations were removed from the dies, placed in a tray, and submerged in water in the heat cup for the final cure. The inlays were removed from the curing unit, returned to the master model, and finished according to conventional laboratory procedures. The completed laboratory result reveals the enhanced optical characteristics and the anatomic morphologic detail that can be achieved with these advanced indirect resin biomaterials.



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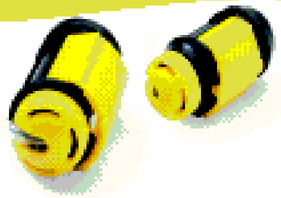

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Adhesive Protocol and Cementation

When anesthesia had been administered to the patient on the next visit, the provisional restorations were removed using a spoon excavator because the material flexes. The cavity preparations were cleaned using hand and sonic instruments and a 2% chlorhexidine digluconate (Cavity Cleanser™) disinfectant. The preparations were rinsed thoroughly to eliminate all the abrasive particles. A throat pack of gauze was placed before removing the provisional and during the try-in of the composite inlay to protect the patient from aspirating the restoration.[23] The restorations were tried in for the evaluation of color and marginal adaptation. The interproximal contacts were inspected and the necessary equilibrations were made. The teeth were isolated with a rubber dam to protect against contamination and to achieve adequate field control.[21,26] A self-priming etchant (TYRIAN™ SPE) was applied to the entire cavity surface with a foam pellet in 2 separate coats, slightly agitated for 10 seconds, and blotted dry with a new foam pellet (Figure 9). A thin layer of single component adhesive (ONE-STEP™ PLUS) was applied onto the primed surface with an applicator tip in 2 separate coats, (Figure 10) air-dried for 10 seconds, and light-cured for 10 seconds per surface. The clear shaded dual-cure composite resin (Illusion™, BISCO, Inc) was used as a cementation material. This adhesive protocol and cementation procedure was performed separately for one preparation and restoration before beginning the other. The inner surfaces of the

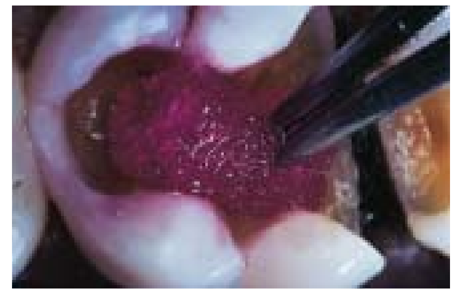

Figure 9—A self-priming etchant was applied to the entire cavity surface with a foam pellet in two separate coats.

Figure 10—A thin layer of single component adhesive was applied onto the primed surface with an applicator tip in 2 separate coats, air-dried for 10 seconds, and light-cured for 10 seconds per surface.

Figure 11—A thin layer of single component adhesive is applied to the internal surface of the inlay, air-dried, and light-cured for 10 seconds.

Figure 12—A sable brush was used to remove the excess resin cement leaving only a small increment at the margin to counteract any polymerization shrinkage of the cement.

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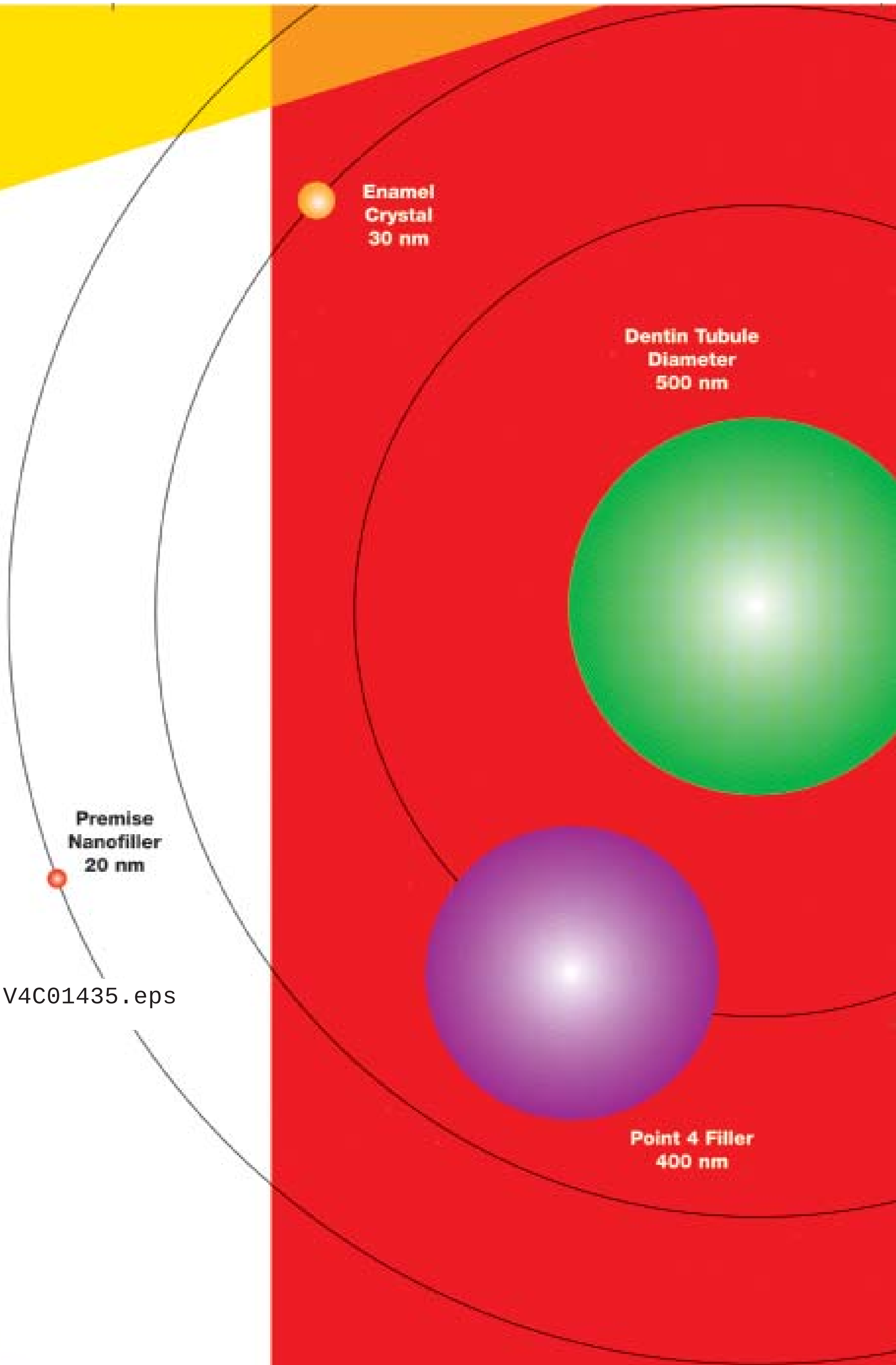

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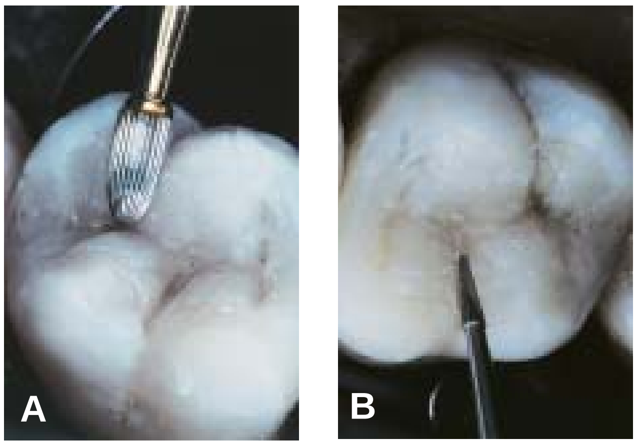


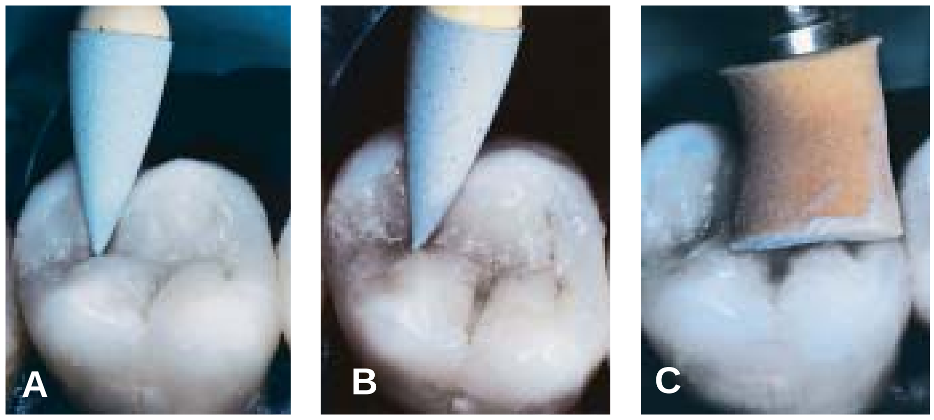
Figure 13A—The occlusal anatomy and cavosurface margins were refined with a 30-fluted, egg-shaped finishing bur.

Figure 13B—A short tapered, needle-shaped finishing bur was used to redefine the occlusal grooves.

Figure 14A—The cavosurface was etched with a 32% phosphoric acid, rinsed, and air-dried.

Figure 14B—A composite surface sealant was applied and cured to seal any cracks or microscopic porosities.

Figure 15—Silicon carbide impregnated brushes were used to polish the occlusal concavities, grooves, and fossae that are difficult to access with other polishing devices.



Figures 16A through 16C—The final polishing was completed with silicone rubber points, pre-polish (A), high-shine (B), and a foam cup (C) with composite polishing paste.

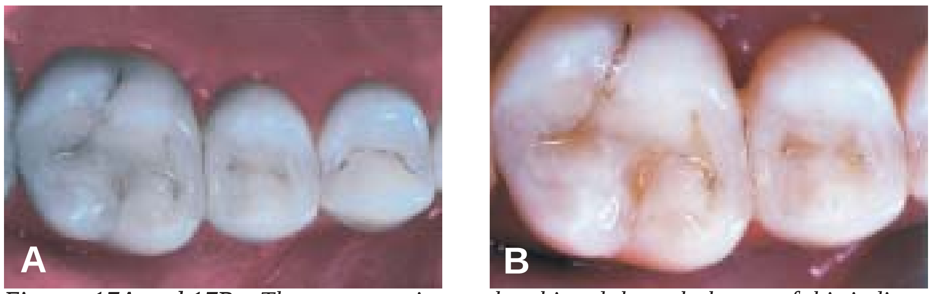
inlays were microetched with a silicate ceramic sand (CoJet™ Sand, 3M ESPE) for 1 to 2 seconds and air-dried. A composite primer was applied to the internal surface of the inlays with a brush in 2 separate coats and air-dried. A thin layer of single component adhesive was applied to the internal surface of the inlays, air-dried, and light-cured for 10 seconds (Figure 11). After the surface treatment, each restoration was cemented with a dual-cure composite cement (Illusion™). The cement was mixed and loaded into a needle tube syringe tip (Centrix, Inc) and injected into the entire preparation. A blunt tip instrument was used to seat and hold the restoration firmly in place. The residual cement was removed with a sable brush (Figure 12), leaving only a small increment at the margin to counteract any polymerization shrinkage of the cement. Initial polymerization is for 4 to 7 seconds for each margin while the restoration is held in place with the blunt tip instrument. A thin application of glycerin was applied to all the margins to prevent the formation of an oxygen inhibition layer on the resin cement.[4] The restoration was polymerized from all aspects: facial, occlusal, lingual, and proximal surfaces each for 60 seconds. After the resin cement was polymerized, any excess at the margin was removed with a scalpel blade (No. 12 Bard Parker, Becton, Dickinson, and Company). After completion of the first restoration, the subsequent restoration was placed using the same protocol.

Finishing and Polishing

The final restorative phase was finishing and polishing, which is critical to the esthetics and longevity of the restored teeth.[27,28] A thorough preoperative occlusal analysis, which is communicated to the laboratory technician through preoperative diagnostic models, an occlusal diagram, photographs, and bite registrations, facilitates the establishment of anatomic morphology and thus minimizes the finishing protocol.[18] To refine the occlusal anatomy and margins, a 30-fluted, egg-shaped finishing bur (RAPTOR®, BISCO, Inc) and a 30-fluted, tapered needle-shaped finishing bur (ET3, Brasseler USA®) were used dry with light pressure to prevent heat build-up. This dry finishing allows the dentist to visualize the margins and contours with the adjacent tooth (Figures 13A and 13B). The interproximal finishing was initiated with a 30-fluted, needle-shaped finishing bur (ET® 3) and completed with aluminum oxide finishing strips (BISCO, Inc). These were used sequentially from coarse to extrafine. After the initial finishing procedure, the margins and surface defects were sealed. All accessible margins were etched with a 32% phosphoric acid (UNI-ETCH®, BISCO, Inc), rinsed, and air-dried. A composite surface sealant (FORTIFY PLUS™, BISCO, Inc) was applied and cured to seal any cracks or microscopic porosities that may have formed during finishing procedures (Figures 14A and 14B). Silicon carbide impregnated brushes were used to final polish the occlusal concavities, grooves, and fossae that are difficult to access with other polishing devices (Figure 15). The restoration is finally polished with silicone rubber points (Diacomp, Brasseler USA®), foam cups (Enhance® foam cup, Dentsply Caulk), and composite polishing paste (Prisma®-Gloss™/ Prisma® Gloss™ Extra Fine, Dentsply Caulk) (Figures 16A through 16C). 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 a 30-fluted, egg-shaped finishing bur (RAPTOR®) and the final polishing was repeated. The contact was tested with unwaxed floss and the margins inspected. The postoperative result demonstrated the true integration of form and color with composite resin to create the beauty of natural esthetics (Figures 17A and 17B).

Conclusion

Although not a panacea to all restorative challenges, these contemporary indirect resin systems provide the patient, technician, and dentist with an alternative approach to various clinical situations. Progress in adhesive technology and composite resin materials allows for not only the creation of an esthetic restoration but also the preservation and reinforcement of tooth structure. This article has attempted to describe the infrastructure of an indirect composite resin system (TESCERA™) and the specific components of this system while providing a detailed description of the preparation, fabrication, cementation, and finishing for an inlay restoration. While the long-term benefits of this next generation formula remains to be determined in future clinical trials, this article has demonstrated that when proper laboratory and clinical techniques are combined with the physical, mechanical, and optical properties of these new biomaterials, the restorative result can provide preservation and conservation of tooth structure, tooth reinforcement, and



Figures 17A and 17B—The postoperative result achieved through the use of this indirect composite resin system reflects the harmonious integration of color, anatomic form, and function.

esthetics. Whereas the evening news may fail to report the technologic advancements that led to the development of this advanced biomaterial, another milestone in the practice of dentistry has occurred on the endless quest for the ideal restorative material. ○

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