

DEVELOPMENT OF A PROCESSED COMPOSITE RESIN RESTORATION: PREPARATION AND LABORATORY FABRICATION

PART I

DOUGLAS A. TERRY¹, KARL F. LEINFELDER²

Advances in the field of adhesive restorative biomaterials have resulted in adhesive restorations that provide increased retention, marginal adaptation and seal, and reduced microleakage. This evolution in adhesive dental technology has dramatically changed the way dentistry is practised in the modern dental office. Modern adhesive restorative materials and techniques now provide clinicians with more conservative treatment avenues to preserve tooth structure while improving the longevity and aesthetics of the dental restoration.

From a wide range of restorative biomaterials, indirect laboratory processed composite resin systems provide an aesthetic alternative for intracoronal posterior restorations. Laboratory processed inlays and onlays fabricated with composite resin are capable of aesthetic results that may also reinforce tooth structure. Because this adhesive procedure strengthens the cusps and provides additional support for tooth structure, more conservative preparation designs can be utilized. These systems restore mechanical and biological function while achieving optimal aesthetic results with minimal resin cement shrinkage and limited tooth reduction. Additional clinical benefits include not only precise marginal integrity, wear resistance similar that is similar to enamel, and wear compatibility with opposing natural dentition but also ideal proximal contacts, excellent anatomical morphology, and optimal aesthetics.^{1,2,3}

Next Generation Indirect Systems

The utilization of laboratory processed composite resin systems for intracoronal restoration of posterior teeth has increased dramatically with the improvements in the physical and mechanical properties of the resin systems as well as patient demand for tooth-colored restorations. These next generation resin systems (TESCERA ATL, BISCO; Gradia Light- Cured Micro-

Ceramic Composite, GC America; Sculpture(r) Plus, Pentron Laboratory Technologies) maintain a higher density of inorganic ceramic microfillers compared to the earlier-generation direct and indirect systems.⁴ These materials have the advantages of both composite resins and porcelains without being confined by the inherent limitations of either⁵.

The biomaterials known as "microhybrids" include a combination of inorganic particles (fillers) and an organic polymer (matrix) with a filler content containing 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 a composite resin material. These submicron-particle fillers demonstrate exceptional surface characteristics including 'polishability' and wear resistance.⁶ The wear is influenced by the filler size, filler shape, filler load and filler/matrix bonding.^{7, 8, 9} In fact, a significant reduction in wear resistance has been reflected by simply decreasing the size of the filler particle.^{7,10}

The various methods of postcuring (e.g., light, heat pressure, vacuum, nitrogen) allow for secondary curing of the composite by increasing the conversion of the material from monomer to polymer.¹¹ This heightened but controlled degree of polymerization increases fracture toughness, flexural and diametral tensile strength, wear resistance, incisal edge strength, and colour stability.^{12, 13} Whereas many studies have examined the plethora of uses for indirect resin reinforced systems, this discussion will focus on the onlay restoration employing an indirect resin reinforced system that uses three curing mechanisms – pressure, light, and heat underwater. Part I will describe 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 preparation and laboratory fabrication.

Components of the System

An understanding of a specific indirect composite resin system requires an appreciation of the components of the system, i.e. the resin material and the curing mechanism. The indirect composite resin system utilized in this case presentation, TESCERA™ ATL™ material (Bisco, Schaumburg, IL) contains a combination of three different forms of composite resin material, these being the dentin, body and incisal components.

¹Douglas A. Terry, DDS

Assistant Professor, Department of Restorative Dentistry and Biomaterials, University of Texas Health Science Center, Dental Branch, Houston, Texas; Private Practice, Esthetic and Restorative Dentistry, Houston, Texas, USA

²Karl F. Leinfelder, DDS, MS, Adjunct Professor, Biomaterials Clinical Research, University of North Carolina, Chapel Hill, North Carolina; Professor Emeritus, University of Alabama School of Dentistry, Birmingham, Alabama, USA.

Composite Resin Material

The filler particle size of the resin material provides the critical data that are essential when selecting a resin material. It also provides information on the optimal utilization of a composite material.¹⁴ The filler particle size, distribution, and the quantity incorporated dramatically affects the mechanical properties and clinical success of composite resins.¹⁵ The filler particles are silanated for suitable adhesion to the organic matrix. The indirect system's filler composition varies for the dentin material and the body and incisal areas. The dentin material is a highly filled hybrid (85% by weight, 73% by volume) similar to the proprietary mixture of the direct restorative AELITE™ LS⁹. This increased filler loading allows a volumetric shrinkage of 1.5% while maintaining a high flexural strength. The body and the incisal material consist of a reinforced microfill (70% by weight) similar to the proprietary mixture of the direct restorative MICRONEWT™ (BISCO, Inc)¹⁶. Added to the nanoparticles is a relatively large "reinforcement" particle that averages 1- μ m in size, compared to the main filler, which is 0.04 μ m in size. The average particle size for this composite is approximately 50 nanometers (0.05 μ m). The presence of these 1- μ m reinforcement particles is reported to contribute to the strength by acting as a "crack arrester," while 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.¹⁶

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 tetraethylene glycol dimethacrylate (TEGDMA). However, the matrix for the incisal differs from that of the dentin and body in that the incisal utilizes 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.¹⁶ The manufacturer suggests that this improved wear resistance of the incisal material is a result of the change in concentration of Bis-GMA.¹⁷

Curing Mechanism

The polymerization process for this indirect system combines two curing mechanisms - light and heat under water. The "artificial dentin" is initially completely pressurized (60 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 this stabilizes the restoration during build-up allowing placement of subsequent increments without deforming the underlying composite layer. After complete development of the restoration, 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 tablet that absorbs the residual oxygen. This is beneficial since oxygen limits the degree of polymerization by competing at the carbon double bond sites. Therefore, removing oxygen allows for a more complete cure since no air-inhibited layer remains uncured,¹⁸ and this may improve the physical and mechanical properties at the surface. The final restorations are cured utilizing an initial full cycle of pressure (60 psi) with light and heat (peak heat of 1300C with the temperature decreasing to approximately 900 C before the pressure is released) for approximately 10 to 13 minutes depending on the size of the restoration and the initial temperature of the water. The final curing process with heat under pressure increases the polymer conversion and eliminates the residual monomers. The resulting composite material provides increased strength and homogeneity, excellent aesthetics with enhanced optical properties and fluorescence, low water absorption and solubility, colour stability, and superior resistance to wear and deformation.²

Fiber reinforcement

For large restorations or teeth with minimal remaining enamel, fibers should be included as a base on which to veneer the composite.¹⁹ An important consideration for achieving optimal long-term clinical success of laboratory fabricated resin inlays/onlays is tooth reinforcement. To reinforce the composite resin, additional fibers (TESCERA Reinforcement Material, Bisco, Schaumburg, IL; Ribbond, Ribbond Inc) are integrated into the resin matrix^{20, 21} during fabrication and before the curing process. These fibers have been surface treated during manufacture to enhance the adhesion to any synthetic restorative material. Although no long-term clinical trials are currently available to determine the clinical success of these materials, a recent short-term study of 60 single-crown restorations demonstrated no breakage after 1 year.^{5, 22} Since the flexural strength and fracture resistance of the restoration are increased by the addition of composite reinforced fibers,^{5, 23} the authors believe it is prudent to incorporate them to reduce fractures in regions of increased occlusal stress.

A recent development of another type of reinforcing structure for these indirect composite resin systems is the TESCERA structural fibrous material (Bisco, Schaumburg, IL), which consists of pre-tensed quartz fibers that are cured into a resin matrix to provide a rigid, strong reinforcing structure. These materials consist of different shapes and configurations (i.e., U-Bars, barrels, sleeves and fiber bundles) which have been surface treated to enhance the adhesion to any synthetic restorative material.

CLINICAL

Preparation, Impression and Provisionalization

The adhesive preparation design preserves sound tooth structure and requires no extension for prevention. The preparation is limited to access to the defect since the composite requires less volume to resist clinical fracture than an amalgam.^{24, 25} Following removal of any carious structure, the cavity design follows the preparation guidelines for indirect inlay/onlay restorations: (Figure 01)

- All enamel should be supported by sound, healthy dentin,
- All internal angles and edges should be rounded to avoid stress and to facilitate the fabrication of the restoration,
- Isthmus width should be at least 2mm with a minimum depth of 1.5mm,
- All proximal walls should be flared or diverged 5 to 15 degrees with no undercuts,
- Gingival margins should be prepared to a 90-degree cavosurface line angle (ie, butt joint),
- Sharp cavosurface margins should be maintained,
- Occlusal margins should not coincide with occlusal contact site,
- No feather-edge preparation. ^{2, 5, 11, 26}

As a general guide, when the isthmus preparation exceeds one-half of the distance from the central fossa to the cusp tip, a restoration with cuspal coverage should be considered. In areas of low stress and where there is minimal potential for tooth flexure, thinner areas of tooth structure may be onlayed judiciously. For larger restorations or weak teeth with minimal enamel, fibers should be included as a base on which to veneer the composite.⁵

Prior to impression taking, it is important to seal the dentin tubules with a hybrid layer.^{1, 11, 27, 28} This protects the pulp from invasion by microorganisms and it also reduces sensitivity during the provisional stage. Once the preparation has been conditioned, a thin layer of adhesive (All-Bond 2, Bisco; G-Bond, GC America; Gluma Confort Bond + Desensitizer, Heraeus Kulzer) is applied to the preparation surfaces with an applicator for 20 seconds, air thinned for 5 seconds, and light cured for 20 seconds. To prevent interaction of the dentin adhesive with the impression material, particularly the polyethers, the adhesive layer is covered with a layer of glycerin and additionally light-cured for 20 seconds²⁹. A polyether impression (i.e., Impregum, 3M ESPE; Permadyne, 3M ESPE; Polyjel NF, Dentsply, Caulk; P2, Heraeus Kulzer) is taken and this should include all cavosurface margins. A direct provisional restoration is then placed with a matrix band (Automatrix, DENTSPLY Caulk) using a light-cured, semiflexible material (ie, Fermit, Ivoclar Vivadent, Amherst, NY) and the occlusion is evaluated.

Laboratory Development

The laboratory procedure (Figures 02-18 A, B) demonstrates how the laboratory processed composite resin is utilized to integrate the existing color of the natural tooth with the optical properties of the restorative material.



Figure 1: Preoperative occlusal view of a defective composite restoration with recurrent caries on the mandibular left first molar.



Figure 2: Photographic custom shade comparison to the natural tooth structure.



Figure 3: Occlusal view of the completed onlay preparation.

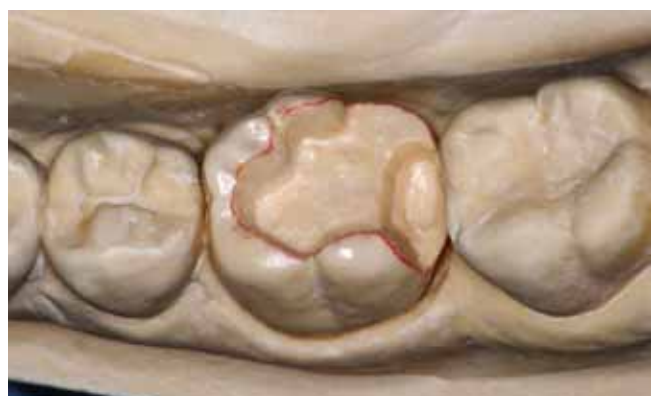


Figure 4: The working model is mounted to facilitate the layering process and the cavosurface margin is outlined.

CLINICAL



Figure 5: A thin layer of die separator is applied to the cavity and to any part of the model that might contact the composite resin and it is then air dried. This layer acts as a separating medium and die spacer.

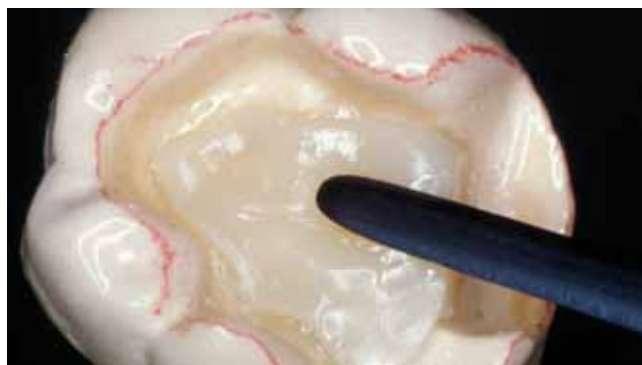


Figure 6: An A-2 shaded opacous dentin layer is placed in the center of the preparation and adapted with a flat-bladed interproximal instrument and an indentation is created around the central artificial core.

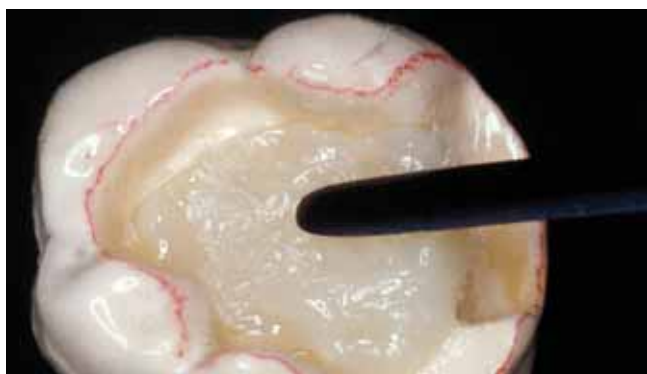


Figure 7: A pre-measured reinforcement fiber is completely coated with unfilled resin and adapted into the soft initial opacous dentin layer and cured in the light cup for 2 minutes.

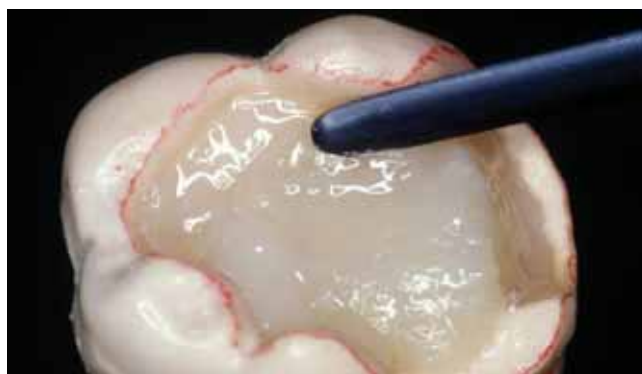


Figure 8: Subsequent increments of A-2 shaded translucent composite are placed and shaped around the dentin core.



Figure 9: A mixture of orange tint with a small amount of red/brown tint is applied in the previously formed invagination. The layers are compressed together creating an internal depth of color within the dentin core.



Figure 10: The occlusal planes and ridges are developed with subsequent layers of opacous and translucent A-2 shaded hybrid composite. Each layer is smoothed and contoured with a 3/0 sable brush and cured in the light cup for 2 minutes.



Figure 11: The die is placed onto the Geller working model and the anatomic contour is developed according to the occlusal parameters.



Figure 12: For the first "artificial enamel" layer, an incisal clear shaded hybrid composite is applied with a flat-bladed instrument to develop the ideal proximal contour and cured in the light cup for 2 minutes.

CLINICAL



Figure 13: Subsequent layers of incisal clear shaded hybrid composite are placed over the developed anatomical contours and a minute amount of orange tint is placed in specific occlusal grooves. The layers are compressed together creating a fine line of stain from the base of the invagination to the occlusal surface and are cured in the light cup for 2 minutes.

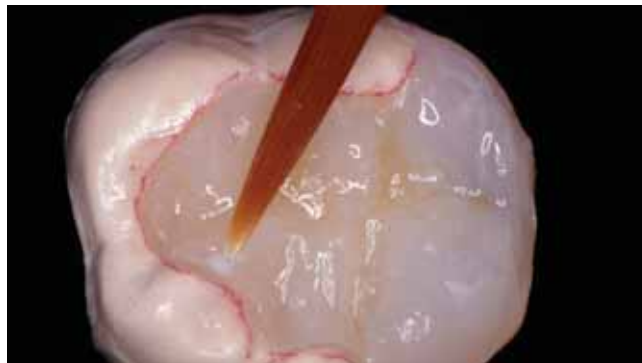


Figure 14: A diluted white tint is placed along the incline planes, cusp tip and the disto-marginal ridge and faded up to the cavosurface margin.



Figure 15: Pits, fissures and grooves are then generated, and a brown-tinted resin is applied with a #.08 endodontic file in the previously formed invaginations according to the shade diagram and cured in the light cup for 2 minutes.



Figure 16a: The final artificial enamel is restored with small increments of incisal clear shaded hybrid composite which are placed over the developed anatomic contours as an occlusal envelope to reproduce form in addition to the optical effects of enamel.



Figure 16b: Developmental grooves are accentuated with an explorer tip.



Figure 16c: The final contours are smoothed with a #2 sable brush.

Conclusion

While the new products and technological advances have had a positive impact on our profession, a new responsibility rests on clinicians and technicians to continually educate themselves and their patients on the properties and applications of the new restorative biomaterials. This knowledge has provided alternative conservative treatment avenues for the resolution of several clinical scenarios. However, it is essential to remember that the final restorative result is based on the experience and judgment of the clinician and technician and the communication and understanding between them. Part one of this discussion has reviewed the general properties of the next generation laboratory processed composite resins, explained

the components of a specific indirect composite resin system (TESCERA™ ATL™, BISCO, Inc). and has provided a detailed description of the preparation and laboratory fabrication of an onlay restoration. Part 2 will describe the principles that should be followed to achieve long-term success with the emphasis on adhesive bonding and finishing protocols.

References

1. Touati, B, Aidan, N. Second Generation Laboratory Composite Resins for Indirect Restorations. J Esthet Dent 1997; 9(3): 108-118.
2. Howard NY. Advanced use of an esthetic indirect posterior resin system. Compendium 1997; 18(10):1044-1054.
3. Leinfelder KF. Indirect posterior composite resins. Compend Contin Educ Dent. 2005;26(7):495-503; quiz 504, 527.
4. Douglas RD. Color stability of new-generation indirect resins for prosthodontic application. J Prosthet Dent 2000; 83(2): 166-170.



Figure 17a, b and c: Silicon carbide impregnated brushes are used to polish the occlusal concavities, grooves, and fossae that are difficult to access with other polishing devices (A) The definitive lustre is accomplished with a soft, white, goat-hair brush and composite polishing paste (B) A high surface reflectivity can be achieved with a dry cotton buff using an intermittent staccato motion applied at conventional speed. (C)



Figure 18a: Completed laboratory processed composite resin restoration (TESCERA™ ATL™, BISCO).



Figure 18b: The enhanced optical characteristics and the anatomical morphologic detail that can be achieved with this advanced indirect system.

5. McLaren EA, Rifkin R, Devaud V. Considerations in the use of polymer and fiber-fiber-based indirect restorative materials. *Pract Periodont Aesthet Dent* 1999;11(4):423-432.

6. Soderholm KJM. Filler systems and resin interface. In: Vanherle G, Smith DC (eds). *International Symposium on Posterior Composite Resin Dental Restorative Materials*. St Paul, MN: Minnesota Mining + Mfg.Co., 1985:139-159.

7. Suzuki S, Leinfelder KF, Kawai K, Tsuchitani, Y. Effect of particle variation on wear rates of posterior composites. *Am J Dent* 1995;8(4):173-178.

8. Braem M, Finger W, Van Doren VE, et al. Mechanical properties and filler fraction of dental composites. *Dent Mater* 1989;5(5):346-349.

9. St. Germaine H, Swartz ML, Phillip RW, et al. Properties of microfilled composites resins as influenced by filler content. *J Dent Res* 1985;64(2):155-160.

10. Bayne SC, Taylor DF, Heymann, HO. Protection hypothesis for composite wear. *Dent Mater* 1992;8:305-309.

11. Miara P. Aesthetic guidelines for second-generation indirect inlay and onlay composite restorations. *Pract Periodont Aesthet Dent* 1998; 10(4): 423-431.

12. Cook WD, Johansson M. The influence of postcuring on the fracture properties of photo-cured dimethacrylate based dental composite resin. *J Biomed Mater Res* 1987; 21(8): 979-

13. Bausch JR, de Lange C, Davidson CL. The influence of temperature on some physical properties of dental composites. *J Oral Rehab* 1981; 8: 309-317.

14. Ferracane JL. Current trends in dental composites. *Crit Rev Oral Biol Med* 1995; 6(4): 302-318

15. Leinfelder KF. Composite resins. *Dent Clin North Am* 1985; 29(2): 359-371.

16. Suh BI. New concepts and technology for processing of indirect composites.

Compend Contin Educ Dent. 2003 Aug;24(8 Suppl):40-42.

17. Oral communication with Steven Duray chemist.

18. Shellard E, Duke ES. Indirect composite resin materials for posterior applications. *Compendium* 1999; 20(12):1166-1171.

19. Jackson RD. Indirect resin inlay and onlay restorations: A comprehensive clinical overview. *Pract Periodont Aesthet Dent* 1999;11(8):891-900.

20. Dickerson, WG, Rinaldi, P, "The Fiber-Reinforced Inlay-Supported Indirect Composite Bridge", *Prac Perio Aesthet Dent* (Supplement) 1996.

21. Touati, B, Miara, P, Nathanson, D, *Esthetic Dentistry & Ceramic Restorations*. London, UK; Martin Dunitz, 1999; pg. 291.

22. Filled Polymer Crowns: 1 & 2 Year Status Report. *Clinical Research Associates Newsletter*, October 1998;22(10):1-3.

23. Dyer, SR, Sorensen, JA, "Flexural strength and fracture toughness of fixed prosthodontic resin composites" *J Dent Res* 1998;77(special issue):160 (Abstract No. 434).

24. Sturdevant CM, Roberson TM, Heymann HO, Sturdevant JR. *The art and science of operative dentistry*. 3rd ed. Mosby-Year Book; St. Louis, MO 1995.

25. Leinfelder, KF. A conservative approach to placing posterior composite resin restorations. *J Am Dent Assoc* 1996; 127:743-748.

26. Burke FJT, Watts DC, Wilson NFH, and Wilson MA. Current status and rationale for composite inlays and onlays. *British Dental Journal* 170: 269-273, 1999.

27. Nakabayashi N, Kojima K, Mashuhara E. The promotion of adhesion by infiltration of monomers into tooth substrates. *J Biomed Mater Res* 1982;16(3):265-273.

28. Pashley DH, Ciucchi B, Sano H, Horner JA. Permeability of dentin to adhesive agents. *Quintessence Int* 1993;24(9):618-631.

29. Magne P, Belser U. *Bonded Porcelain Restorations in the Anterior Dentition A Biomimetic Approach* 1st ed 2002; Quintessence Publishing Carol Stream, IL.