Development of a Processed Composite Restoration: Adhesive and Finishing Protocol

Part II

DOUGLAS A. TERRY[1], KARL F. LEINFELDER[2]

The first part of this discussion provided an overview of the general properties of the next-generation laboratory processed composite resins and described the preparation and laboratory fabrication of an onlay restoration. The second part of this discussion will describe the principles that should be adhered to in achieving long-term success with these restorations and it will explain the use of these principles in adhesive bonding and in finishing protocols.

Optimizing the adhesion of restorative biomaterial to the mineralized hard tissues of the tooth also enhances the mechanical strength, marginal adaptation and seal while improving the reliability and longevity of the adhesive restoration. The search for a tooth-restorative interface to mimic the natural tooth condition has resulted in the establishment of an effective micromechanical bond between the composite and the mineralized tooth structure. Surface alterations of dental tissue substrates (enamel and dentin) for adhesive application of composite material have provided the following clinical benefits for bonded restorations:

- Reduced need for mechanical retention and resistance form thus conserving sound tooth structure,
- Restoration of tooth integrity and fracture resistance,
- Improved marginal seal,[1,2]
- Reduced sensitivity,
- Reinforcement of remaining enamel and dentin,
- Cusp reinforcement after tooth preparation in posterior teeth,[1,3,4]
- Retention for composite restorations,[1,5]
- Reduction or elimination of marginal microleakage.[1,2,6-10]

[1]*Douglas 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
[2]*Karl 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.*

Adhesive Concepts for Indirect Composite Resins

Indirect laboratory processed composite resin restorations provide an effective alternative to the polymerizing composite resin mass that is placed directly into a cavity with its inevitable adverse polymerization shrinkage forces. In addition, adhesive bonding of laboratory-processed composite resins increase their resistance to fracture and they have the potential for tooth strengthening.

Principal determinants of the long-term success of these restorations are the strength and durability of the interface.[11] This adhesive joint consists of a complex bond which includes three interfaces: tooth-resin interface, resin-luting resin interface, and the luting resin-composite interface. Several factors that influence this adhesive joint should be considered. These are:

1 the thickness of the resin cement,
2 the restoration fit,
3 stabilization of the hybrid layer, and
4 the wear of the luting cement.

A well adapted restoration should have a marginal fit of 100 microns. However, the use of dye spacers may increase that dimension to 300 microns.[12,13] With thin layers of resin cement, the polymerization shrinkage is primarily directed uniaxially.[12,14] Under normal clinical conditions, the resulting "wall to wall contraction" of the composite is proportional to the thickness of the cement. Consequently, well adapted restorations will reduce the polymerization strains applied on the adhesive interfaces and provide improved internal adaptation and seal.[12] Although tightly fitting restorations can lock inside the cavity and prevent micro-movements of the restoration or the tooth, larger cementing spaces can partially compensate for the polymerization forces by allowing the restoration and tooth to move slightly during the luting procedure. Marginal integrity with a passive insertion is the ideal clinical situation.

Furthermore, the vertical loss of the luting agent is related in part to the interfacial width between the wall of the preparation and the restoration itself. A clinical study at the University of Alabama has determined that the vertical loss of cement approximates the width by 50%.[15, 16] A marginal gap that is 200 microns at the time of cementation will result in a wear of the cement by 100 microns.

Pre-curing the bonding resin after acid etching at the cementation appointment can prevent correct positioning of the restoration. A pre-hybridization, dual bonding or resin bonding at the first appointment prior to the impression will stabilize the hybrid layer and prevent ingress of microorganisms through the dentinal tubules, thus diminishing tooth sensitivity during the provisional phase. Additional curing of the adhesive through a layer of glycerin is suggested to remove the oxygen inhibition layer and to prevent interaction of the dentin adhesive with the impression material (particularly the polyethers). [17, 18] The wear pattern of resin luting cements on occlusal surfaces is greater than with restorative composites[15] and since the occlusal wear is directly proportional to the interfacial gap[19], the cementing gap should be reduced, occlusally.[12] (Figure 01, Figure 02). The proper sequence in the luting procedure may balance this complex interplay between polymerization shrinkage and adhesion and improve marginal adaptation and seal while improving bond strength. Polymerization stress at the interface will also be reduced.

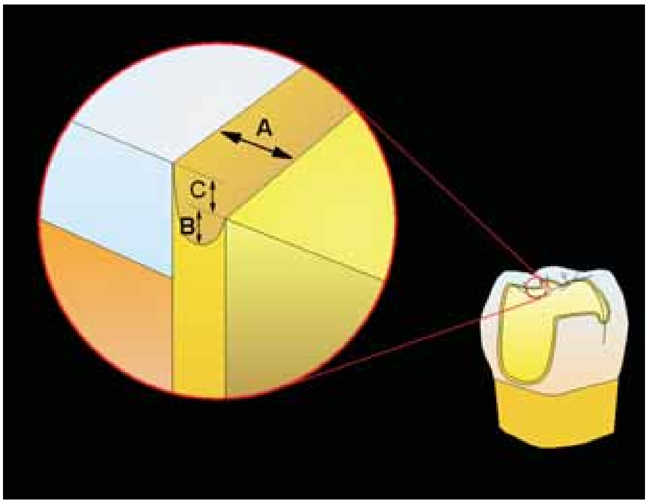

Figure 1: Diagram illustrates the wear pattern of composite luting cements with occlusal surfaces. Note the cement undergoes vertical wear until approximately half of the cementing space width is attained. (Adapted from Leinfelder at al, 1993 and 1995)

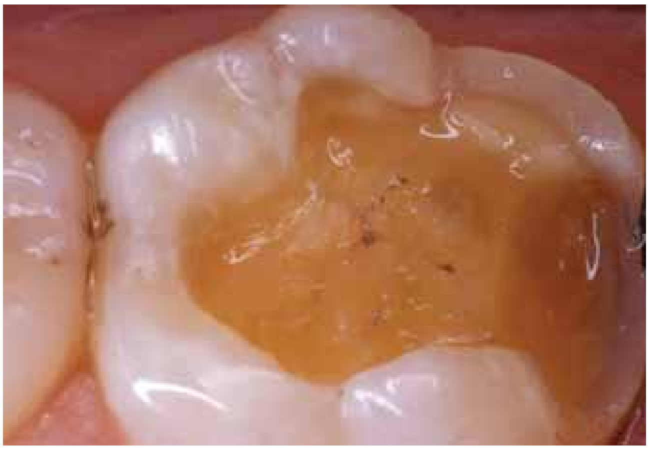

Figure 2: Completed onlay preparation design.

Clinical Considerations for Improving Adhesion and Finishing of Laboratory Processed Composite Restorations

The clinical success of a composite restoration is determined by function, aesthetics, biocompatibility, and longevity.[20] The attainment of these four criteria begins at the adhesive interface. A restorative material properly bonded to the enamel and dentin substrate will reduce marginal contraction gaps, microleakage, marginal staining and caries recurrence, and improve retention. It will also reinforce tooth structure and dissipate and reduce functional stresses across its interface throughout the entire tooth while improving the natural aesthetics and wear resistance.[21-25] The clinical considerations that follow are essential elements in achieving these criteria.

A fundamental requirement for successful bonding is the use of the rubber dam. Contamination of the enamel and dentin with saliva, moisture from intraoral humidity or blood and crevicular fluid can compromise the longevity of the adhesive restoration by affecting the adhesion at the interface and reducing bond strengths.[26,27] Numerous studies report microleakage, reduced adhesion and bond strength reduction from contamination of enamel with saliva,[28-31] moisture,[32-37] and contamination from crevicular fluid.[37]

In saliva contamination, the saliva acts a film barrier at the contact level between the resin and the enamel. Thus, the surface energy of the enamel is lowered and optimal adhesion is prevented.[31] Also, saliva contamination of the etched surface of the enamel affects the morphological characteristics of the surface and the glyco-proteins in the saliva block the micropores which are formed during the etching procedure as reported by Hormati and others.[30,27] Moisture contamination from intraoral humidity can form a thin layer of moisture on the etched enamel which could prevent maximum adaptation between resin composite and enamel surfaces. This phenomenon has been reported by Jorgensen[32,33] and Fujii et al.[32,34] Moisture contamination from crevicular contamination has been reported to reduce bond strength of composite to etched enamel by 70%.[37,38] An in vivo study demonstrated that composite resin bonded to etched enamel surfaces using rubber dam isolation has significantly less microleakage than that which occurs with cotton roll isolation.[31,32] Therefore, for optimally bonded composite restorations moisture control is essential throughout the adhesive procedure. This requires adequate insulation and isolation of the operating field with rubber dam.[39]

The tooth-restorative interface is constantly subjected to polymerization shrinkage stress. Before a restoration is even

Figure 3: The preparation and occlusal surface are cleaned with 2% chlorhexidine.

subjected to functional loads and thermal strains there is an initial interfacial stress which develops during the polymerization of restorative materials and their adhesion to tooth structure.[40] Therefore, a comprehensive understanding of the complex interplay between polymerization shrinkage and adhesion is advised. The cross-linking of resin monomers into polymers is responsible for an unconstrained volumetric shrinkage of 2 to 5%.[41] The uncompensated forces may exceed the bond strength of the tooth-restoration interface resulting in a gap formation from a loss of adhesion.[42] Bacterial and fluid penetration through the marginal gaps may occur causing colonization of microorganisms,[43] recurrent caries and postoperative sensitivity with possible subsequent irritation of the pulp;[44] all of which effectuate clinical failure.[45,46] However, these phenomena are more specific to direct restorations with certain cavity configurations (C-factors). Since indirect restorations are polymerized outside of the oral cavity, shrinkage stress is less of a concern because of the limited volume of the resin luting cement.

Changes in the chemical composition of the dentin as a result of response to various stimuli could compromise an adhesive procedure. Alterations in the mineral content and structure of the of the dentin can be as a result of age, caries, or external stimuli from the oral cavity (i.e. abrasion, abfraction, or erosion lesions).[47,48] The peritubular cuff might increase in thickness towards the center of the tubule resulting in calcified blockage of the tubular lumen.[49] Dentin which has experienced such microstructural modification is termed sclerotic dentin.[7, 50] These sclerotic regions are hard, dense, and calcified and serve to protect the pulp from subsequent stimuli. When there is significant sclerosis, the dentin commonly becomes dark yellow or discolored with a glassy or translucent appearance. These calcified regions are resistant to acidic conditioning solutions and therefore resin penetration is limited and the hybrid formation is very thin[51,52] presenting a challenge to consistent and reliable bonding. Therefore, during the diagnostic and treatment planning phase, the clinician should focus attention on the differing dentin compositions in preparation for the proper restorative modality.

The proper finishing and polishing protocol can influence the longevity of indirect restorations by affecting wear resistance,[53,54] and marginal integrity. Delayed finishing and polishing with various techniques results in a surface of similar hardness to or even harder than that obtained with immediate finishing. The effects of delayed finishing appear to be bonding system and tissue specific.[55] The bond strength of resin to enamel and dentin is higher at 24 hours than immediately after placement.[56,57] Since some of this improvement occurs within several minutes after placement of the restoration, it is suggested that a brief delay in the finishing procedure may help to preserve the marginal integrity.[56]

The next-generation formulations of microhybrids have components with finer filler size, shape, orientation and concentration, and in combination with a higher degree of conversion through post-curing, their physical and mechanical characteristics are improved[58-62] thereby allowing the resin composite to be polished to a higher degree.[59] The variation in hardness between the inorganic filler and the matrix can result in surface roughness since these two components do not abrade uniformly.[59,60] Accordingly, it is imperative that the surface gloss of the restorative material and tooth interface are similar because the gloss can influence color perception and shade matching of the restoration and tooth surface. [61,62]

The surface aesthetics of a composite resin restoration are a direct reflection of the instrument system utilized.[63] The surface of the composite can be finished and polished with a variety of techniques. Diamonds, multi-fluted burs, discs, polishing points and cups have all been used to reproduce the shape, color, and luster of the natural dentition. As Pratten and Johnson have indicated, there is no difference between finishing and polishing anterior and posterior restorative materials.[64] The consideration factors for finishing and polishing any restoration are dependent on the instrument shape, the surface shape and texture of the tooth and restoration, the surfaces of the finishing and polishing instruments, as well as the sequence of the restorative procedure.[64]

The margins of indirect composite restorations should be re-etched and sealed with low-viscosity resins. (Fortify Plus, Bisco; PermaSeal, Ultradent) Application of a composite surface sealant after the initial finishing procedure may help to seal microcracks or microscopic porosities that formed during the procedure. In addition, this application has been shown to reduce the wear rate of posterior composite restorations.[65,66]

The Clinical Procedure

Adhesive Tooth Surface Preparation

At the time of final bonding of the restoration, a gauze throat pack is placed prior to removal of the provisional and during try-in of the composite inlay to protect the patient from aspirating the restoration.[67] The provisional is removed and the restoration is tried in for the evaluation of colour and marginal

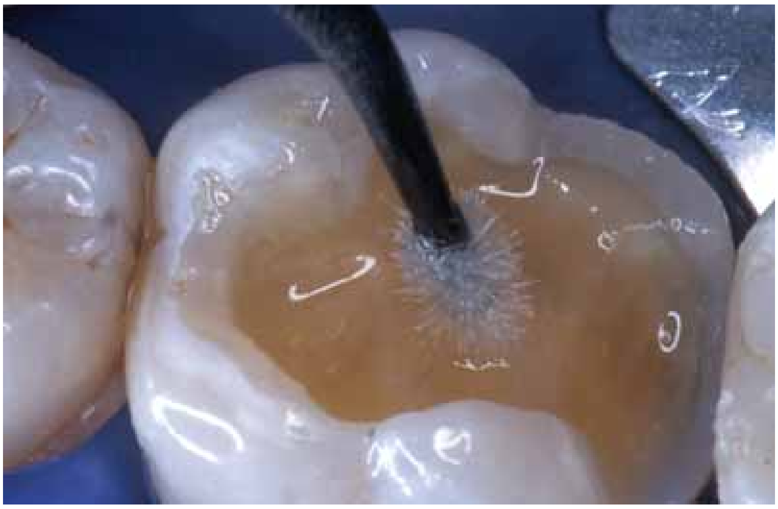

Figure 4a: A thin layer of single component adhesive was applied with an A, Bapplicator tip in 2 separate coats (A) ; air thinned for 10 seconds

Figure 4b: Light- cured for 10 seconds per surface.

Figure 5a: The internal surface of the onlay was microetched with silicate A, B sand for 1 to 2 seconds and air-dried.

Figure 5b: a composite primer was applied to the internal surface with a brush in 2 separate coats and air-dried.

adaptation. The interproximal contact is inspected and necessary equilibrations are made. The teeth are isolated with a rubber dam to protect against contamination. This process involves the creation of an elongated hole that allows placement of the rubber dam over the retainers to achieve adequate field control.[68,69] The cavity preparation is cleaned with a slurry mixture of disinfectant and pumice (Consepsis, Ultradent, South Jordan, UT) to remove the prehybridization layer and (Figure 03) and it is then rinsed thoroughly to eliminate all the abrasive particles. The total etch technique is utilized due to its ability to minimize the potential for microleakage and to enhance bond strength to dentin and enamel.[70-72] A soft metal strip is placed interproximally to isolate the prepared tooth from the adjacent dentition. The preparation is etched for 15 seconds with 32% phosphoric acid semi-gel with benzalkonium chloride(Uni-Etch with BAC, Bisco; Ultra-Etch 35%, Ultradent; Scotchbond Etchant, 3M ESPE), rinsed for 5 seconds, and lightly air dried to avoid dessication. Once the dentin and the enamel have been remoistened with a rewetting agent (AQUA-PREP™ F, Bisco) on an applicator, a hydrophilic adhesive system is utilized. A dual-cure composite resin (DUO- LINK™,a, Bisco) is preferred as a cementation material. A single component adhesive (ONE-STEP, Bisco) is applied in 2 to 3 coats with an applicator with gentle agitation, air dried for 10 seconds and light-cured for 10 seconds. (Figure 04 a,b)

Adhesive Surface Preparation of Restoration

The surface of laboratory-processed composite resins is highly polymerized with very few unreacted free-end radicals for bonding to the resin cement. While microleakage has been reported to occur at this interface between the internal surface of the inlay/onlay and the resin cement in the absence of composite softening agents,[73] several surface treatments have been advocated to promote adhesion between the resin cement and the indirect composite restoration. Mechanical roughening of the internal surface of the inlay can be accomplished with small particle diamond burs or microetching with either 50 µm aluminum oxide particles or 30 µm silanized silica-coated aluminium oxide particles which creates a micromechanical retention bond at a microscopic level between the restorative material and the resin cement. In addition to mechanical roughening, an application of proprietary softening agents, wetting agents, or silane has been reported to enhance the bond strength between the restoration and the resin cement.[74]

The manufacturers of the indirect resin systems have recommended various pre-cementation protocols. The authors' standard cementation protocol for laboratory-processed composite resins includes microetching with a silicate ceramic sand (Cojet-Sand, 3M ESPE) and subsequent application of

Figure 6: Excess resin cement was removed with a sable brush.

Figure 7: After polymerization, any excess resin cement was removed with a scalpel blade.

Figure 8: The occlusal margin was finished with a #30 fluted egg shaped finishing bur

Figure 9: The cavosurface margins were re-etched, and a composite surface sealant was applied and light-cured to seal any microscopic porosities that may have formed during the finishing procedure.

silane to restore any coating on the original fillers that might have been removed by sandblasting. As a bifunctional molecule, the silane acts as a coupling agent between the filler particles on the indirect resin surface and the resin cement. Newer formulations of silane that include a monomer (i.e., unfilled resin) further simplify the bonding process. Microetching of aged composite resins with silica-coated aluminum oxide particles results in higher bond strengths when compared to other surface treatments for intraoral repair of composites.[75] The mechanism of this action is to allow the silicate particles to become embedded on the surface of the restoration (during sandblasting), which then reacts with the silane to improve bond strengths.[76] Reports indicate, however, that etching or rinsing after such surface treatment can significantly decrease shear bond strengths.[74, 77] (Figure 05 a. b)

Adhesive Bonding of Onlay Restoration

After the surface treatment the restoration is bonded with a dual-cure composite cement (DUO- LINK ™,a,Bisco; RelyX™, 3M ESPE; Variolink II, Ivoclar Vivadent). The cement is mixed and loaded into a needle tube syringe tip (Needle Tube, Centrix, Sheldon, CT) and injected into the entire preparation. A blunt tip instrument is used to seat and hold the restoration firmly in place and the excess cement is removed with a sable brush.

(Figure 06) It is imperative to leave a residual amount of cement to prevent voids and to compensate for the polymerization shrinkage of the cement. Initial polymerization is for 20 seconds while the restoration is held in place with the blunt tip instrument. The residual cement is then removed with a sable brush and the interproximal surface is flossed leaving only a small increment at the margin to counteract any polymerization shrinkage of the cement. A thin application of glycerin is applied to all the margins to prevent the formation of an oxygen inhibition layer on the resin cement.[71] The restoration is polymerized from all aspects, facial, occlusal, lingual, and proximal, each for 60 seconds. After the resin cement has been polymerized, any excess at the gingival margin is removed with a scalpel (#12, Bard Parker, Franklin Lakes, NJ).(Figure 07)

Finishing and Polishing Protocol

The fabrication of indirect composite resin restorations requires careful development and shaping within the confines of the preoperative occlusal registration prior to curing of the material. This facilitates the establishment of anatomic morphology and minimizes the finishing protocol.[78] A meticulous finishing protocol may increase the longevity of the restoration.[79,80] The smoothness of the composite surface is dependant on the curing system, the components within the restorative material, and the finishing instruments.[81] The gingival and interproximal regions are finished with # 30 fluted needle-shaped finishing burs (Composite Finishing Preparation Kit, Bisco; ET-6,Brasseler USA,) and the occlusal anatomy is refined with #30 fluted egg-shaped finishing burs (9406 Midwest; R.A.P.T.O.R. posterior finishing bur, Bisco (Figure 08). After the initial finishing procedure, the margins and surface defects are sealed. All accessible margins are etched with a 32 % phosphoric acid semi-gel, rinsed and dried. A composite surface sealant (Fortify, Bisco) is applied and cured to seal any cracks or microscopic porosities that may have formed during the finishing procedures. (Figure 09) The restoration is finally

Figure10a: Final polishing was accomplished with pre-polish (A) and high A, B ,C shine.

Figure 10b: Silicone finishing points.

polished with rubber points and cups (pre-polishDC1M, high shine DC1, Brasseler USA; Composite polishing kit, Bisco) and composite resin-polishing paste. (Figure 10 a, b, c) The proximal surface is smoothed with polishing paste and plastic finishing strips. The rubber dam is removed and the patient is prompted to bring the teeth together without force and then to perform centric, protrusive, and lateral excursions. Any necessary equilibration is accomplished with a #12 and #30 egg-shaped finishing bur (Composite Finishing Preparation Kit, Bisco; OS1[a], Brasseler USA,) and the final polishing is repeated. The contact is tested with unwaxed floss and the margins are inspected. The final result illustrates the harmonious integration of composite resin with existing tooth structure. (Figure 11)

Conclusion

As the restorative philosophy for the modern dentist changes, the mind set of the clinician must be transformed to continue to explore and develop ideas, techniques and protocol. However, the knowledge and desire to create are limited by the products clinicians have available to them for restorative procedures, and knowledge must be integrated with the proper technique for each clinical situation. Considerable progress in adhesive technology and indirect restorative systems have allowed the clinician to create aesthetic restorations that not only preserve, but reinforce tooth structure.

Dental research is leading the way with the new advances in restorative materials and adhesive technology. These techniques, concepts and ideas from clinicians, scientists and technicians around the world are the sparks that ignite the reaction. However, it is the experience and judgment of the clinician and technician that is the "true catalyst" of the reaction that creates form, function, aesthetics and longevity.

Therefore, by working together in proper sequence, the clinician and ceramist team can develop restorations that are biologically and mechanically sound. Only through continued education, commitment to excellence, and communication (both quantitative and qualitative) between clinical and laboratory colleagues can restorations that reflect the continuous progress in aesthetic and restorative dentistry be fabricated and delivered.

Figure 10c: To increase smoothness and surface reflectivity a foam cup was used with a loose abrasive diamond polishing paste (C).

Figure 11: The postoperative occlusal view of the definitive restoration. Note the optical integration and marginal integrity of the laboratory processed composite resin onlay with the existing tooth structure.

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