Current Clinical Concepts for Adhesive Cementation of Tooth-Colored Posterior Restorations

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The adhesive luting of tooth-colored posterior restorations has long been considered an unreliable clinical procedure. The physical and clinical properties of former base lining materials, the absence of an effective peripheral biological seal during provisionalization, and the use of less than optimal adhesive systems and luting cements have prevented the achievement of satisfactory clinical results. This article describes effective procedures for adhesive cementation based on the application of distinctive layers and the use of densely filled, viscous luting materials.

Despite significant improvements in the composition and performance of composite resins, these materials still exhibit a considerable degree of polymerization shrinkage,[1-3] which limits their use in direct restorations. The important limitations are related to the immediate and delayed stresses generated by the polymerization of composite resin (Figure 1),[4-6] the inadequate performance of current dentin adhesives,[7] and the difficulty in producing ideal proximal and occlusal anatomy.[8]

The use of compensatory techniques, such as the various composite layering systems, the incorporation of a composite resin or ceramic insert, or the application of a glass-ionomer base, has been suggested as a means to minimize the stresses developed in adhesive interfaces (Figure 1A).[9,10] However, the efficacy of these approaches appears to be limited and controversial,[11] and this proposal does not solve the problem of spontaneously delayed polymerization,[4] which also generates stresses in proportion to the volume of composite cured in situ (Figure 1B).[12]

Despite high tensile or shear bond strengths that have been measured in vitro,[13-15] dentin bonding agents are not fully effective in a clinical configuration following an

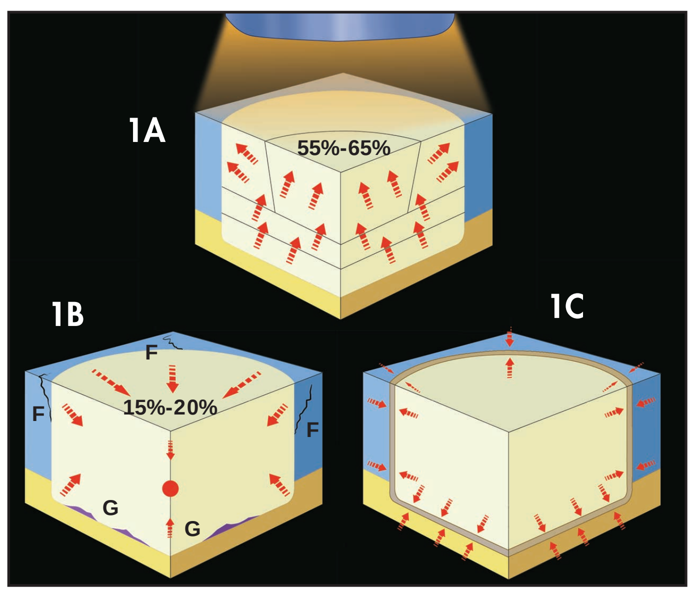

Figure 1A. Light-induced composite polymerization shrinkage. 1B. Increase of stresses generated by spontaneous and delayed polymerization can result in fissures (F) and gaps (G). 1C. Adhesive cementation of a fully polymerized restoration provides stability prior to placement.

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actual restorative sequence.[7,16] In vitro tests seem to bear little relevance to the clinical efficacy of dental bonding agents.[17] The intraoral utilization of composite resin in deep and wide cavities or in serial restorations also has limitations in regard to the correct anatomy and function of occlusal and proximal surfaces. Therefore, a semidirect or an indirect approach has been suggested for cases with extensive defects as a means to compensate for the remaining deficiencies of direct restorative materials (Figure 1C).[8]

Luted restorations, particularly in indirect cases, are still considered to be a restricted treatment option, due to the difficulties encountered in provisionalization, potential leakage under the provisional restorations, and postoperative sensitivity. The technique-sensitivity of the luting procedure must also be addressed. The purpose of this article is to review recent concepts in luting procedures and materials that have been developed to overcome these clinical limitations.

Evolution of Concepts and Procedures

It has been demonstrated recently that aesthetic and durable results can be achieved in vivo with luted ceramic restorations, provided the indications and the laboratory and clinical procedures are strictly observed.[18] However, the less experienced clinician may justifiably expect a simplification of this treatment modality, particularly in regard to the adhesive cementation of tooth-colored restorations.

Figure 2. All remaining temporary cement debris must be removed in order to achieve an optimal adhesion of the luted restoration with the base and tooth structures.

Figure 3. Following the manual cleaning, some temporary cement may remain in place. It can be efficiently removed with an air powder device.

Figure 4. Occlusal view of the cleaned cavities prior to the adhesive and luting procedures.

Figure 5. Preoperative clinical view of a defective composite filling.

Adhesion to Dentin

While effective adhesion to acid-etched enamel is predictably achievable, bonding to dentin relies on more complex phenomena. The formation of a hybrid layer is influenced by several clinical steps, including the polymerization of the bonding resin, which stabilizes its structure. Previous bonding procedures were performed just prior to cementation, without the possibility of curing the bonding resin to allow precision placement of the

Figure 6. The cavity is based with a flexible compomer material in order to achieve an adequate geometry for a semidirect composite inlay.

Figure 7. The restoration is completed chairside on a silicon model.

Figure 8. Postoperative clinical view of the restoration following 1 year of clinical service demonstrating the satisfactory performance of bonding procedures.

restoration. This resulted in an insufficient bonding efficiency, probably due to a collapse of the frail hybrid layer structure under the pressure of the cementation process.[7,19] This approach was utilized due to the mistaken belief that, in the absence of the oxygen-inhibited layer, it would not be possible to develop efficacious adhesion between the bonding resin and the luting composite. It was demonstrated only recently that effective adhesion can be achieved by applying the adhesive immediately following preparation, despite further "contamination" of the adhesive interface by impression and provisionalization materials.[20]

It had been suggested previously that a significant reduction of the bond efficiency would result if the adhesive were not applied initially, and the dental tissues were allowed to become physically or chemically contaminated by the impression material or provisional cement (Figures 2 through 4).[21-23] It has also been proposed that the reliance on immediate application of the adhesive was based on the attempt to stabilize the adhesion prior to subjecting the adhesive interface to the stresses of subsequent restorative steps. Contemporary research has demonstrated that the initial performance of dentin adhesives immediately following application is significantly inferior to the definitive bond strength.[24]

Biological Protection

Postoperative sensitivity is known to be a symptom of bacterial contamination or hydrodynamic phenomena.[25-28] The occurrence of these complications may be avoided by an initial application of the adhesive. As aforementioned, this modification in the operative sequence is likely to improve bonding efficiency and provide effective biological protection during the provisionalization process. The temporary cements cannot provide an efficient seal, since these cements are rapidly washed out of the margins and do not prevent incidental temporary decementation.[29,30]

Figure 9. Preoperative view of a maxillary quadrant to be restored due to recurrent and new interproximal carious lesions.

Provisionalization

When the cavity is properly isolated by the adhesive or base material, a soft light-curing resinous material (eg, Fermit and Fermit-N, Ivoclar Vivadent, Amherst, NY) can be used. The application of this material is simple and effective, and this option has been found clinically acceptable for brief intraoral service.[31] When compared with the classic utilization of cemented provisional restorations, fabricated with a self-curing acrylic resin, this option reduces the duration of the chairside treatment.

Geometry

The indirect approach requires that the cavity has a proper design, with taper, minimal undercuts, and supragingival margins; application of a base must also comply with these requirements. It is also important to preserve the highest degree of sound tissues and to obtain a thin and regular layer of luting cement in order to control polymerization stresses during cementation (Figures 5 through 12).[32] In cases with slightly subgingival margins, it is possible to relocate the cervical preparation supragingivally by applying the appropriate increment of composite resin over the existing margin. This procedure must be performed under rubber dam isolation, following the placement of a matrix.

Table 1

Young's Modulus of Elasticity of the Natural Tissues and the Restoration Layers

Material	E-Modulus (GPA)
Dentin	12* to 19†
Enamel	50*
Hybrid layer	8.2 to 9.7†
Adhesive resin	1.5 to 4.8‡§
Compomers	7.4§
Flowable composites	3.6 to 7.6‖
Restorative composites:	
Microfilled	5.4 to 11.9‡§
Hybrids	10.6 to 27.4‡§
Ceramics:	
Feldspathic	50 to 100§
Aluminous	380§
Zirconium	200§

* Reference 10
† Reference 32
‡ Reference 53
§ Manufacturer's Data
‖ Reference 54

Figure 10. The impaired tissues have been removed. The cavity geometry is not yet adequate.

Figure 11. Base areas of the cavities were treated with a glass ionomer cement, following the classic approach. Degradation of the cement by dehydration is evident.

Progressive Flexibility/Elasticity

The importance of incorporating an elastic layer in the base of the restoration has been emphasized previously. The layer compensates for polymerization shrinkage and acts as a stress absorber.[33] This role can be assumed by the hybrid layer,[34] the bonding resin,[33,35] or a soft base liner.[36-38] Resin-modified glass-ionomer and compomers are two materials that may be utilized with indirect restorations to form a resistant but less rigid base. This base can also preserve adhesion, due to a reduced and slower development of polymerization stresses.[38-40] Flowable composites constitute another option as a base lining material. This group of materials exhibits unique physical properties, such as an acceptable compressive strength,

Figure 12. Postoperative view of the composite inlays following 2 years of clinical service.

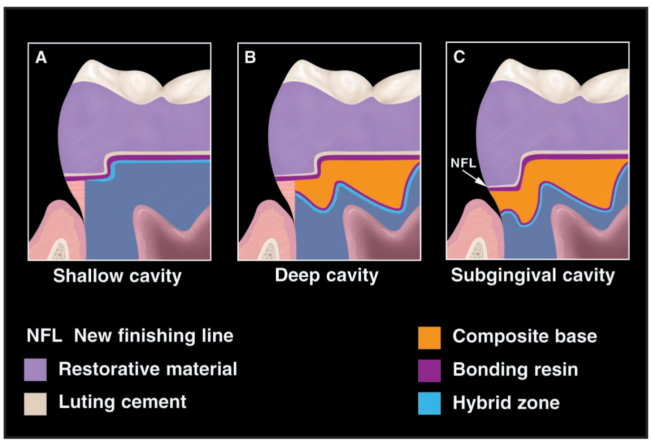

Figure 13. New stratification concepts for luted restorations according to cavity configuration: 13A. Shallow cavity. 13B. Deep cavity. 13C. Subgingival cavity.

but lower modulus of elasticity. Due to their increased flexibility (in comparison with restorative composites), compomers and flowable composites have the potential to reduce the stresses within the adhesive interfaces during polymerization contraction. Moreover, the application of these "flexible" materials in small amounts, with a favorable configuration (large free surface) also contributes to the control of polymerization stresses. When the existing preparation does not provide the space required for application of a compomer or flowable composite as a base liner, a thick layer of bonding resin (eg, Optibond or Optibond FL, Kerr, Orange, CA) has to cover all dentin surfaces to assume a similar role (Figure 13). The only contraindication to the initial application of the adhesive and resinous base liner is the difficulty of proper isolation of the preparation from the restorative material in the intraoral semidirect technique (Figures 14 through 18).[8]

The current approach in adhesive restorations is based on the "progressive flexibility" concept to accommodate polymerization contraction of current composite resins and to partially absorb functional stresses through several layers of increasing rigidity (Table 1). The purpose of the layering technique is to match the assemblage of natural tissues, which also increases tissue rigidity from the pulp/dentin interface to the enamel surface. However, it must be remembered that excessive flexibility can adversely affect marginal and internal adaptation, due to increased deformation. In order to optimize the clinical benefits of this innovative concept, the ideal modulus of elasticity of the various restorative components still has to be established.

Thickness of Luting Cement

It is now recognized that the polymerization shrinkage is directed primarily uniaxially in thin layers of resin cement.[41] Under general clinical conditions, the resulting "wall-to-wall contraction" of the composite is proportional to its thickness.[19,32] Consequently, well-fitting restorations reduce the polymerization strains exerted on the adhesive interfaces and should provide improved adaptation and seal.

Figure 14. Preoperative view of a maxillary first molar, exhibiting a fracture of the buccal cusp.

Figure 15. The tooth is prepared for a semidirect intraoral composite restoration. The cavity is insulated with a separating liquid.

Figure 16. The restoration is built up intraorally with several increments of composite resin.

Figure 17. Try-in of the restoration following intra- and extraoral curing.

However, a large cementing space partially compensates for the polymerization stresses, allowing the tooth structure and the restoration the opportunity to undergo micromovements during the luting procedure.[19,32,42] Perfectly fitting units are more likely to lock inside the cavity during placement and impede any compensatory movements, such as restoration descent and flexion of the remaining walls. In the clinical setting, the ideal restoration should provide an excellent fit with a passive insertion.

Wear of the Luting Cement

It is documented that luting composites undergo more extensive wear than do restorative composites,[43] and that occlusal wear is proportional to the interfacial gap.[44,45] Therefore, it is important to reduce the cementing gap, at least occlusally. The current trend is to use highly filled dual-cure composite resin, such as the materials developed for ultrasonic-assisted cementation (eg, SonoCem, ESPE, Norristown, PA; Variolink Ultra, Ivoclar Vivadent, Amherst, NY)[46] or restorative materials that are even more wear resistant. The higher viscosity of these composite resins requires the additional use of the ultrasonic energy to facilitate a complete seating of the restoration. The expected benefit is to reduce or postpone the channeling effect at the level of occlusal margins.

Curing of Adhesive Luting Cements

Since chemical activation is often insufficient to fully stimulate dual-cure composite resins, proper light activation remains essential to ensure an optimal conversion rate of the material.[47-49] It has been demonstrated recently that proper light activation is possible through ceramic inlays.[50] The use of a light-curing restorative material for the cementation of tooth-colored restorations should no longer be considered a hazardous procedure. The complete

Table 2

Summary of the Changes and Improvements in Indirect Techniques

Clinical Step	Classical Approach	Modern Approach
Adhesive application and dentin sealing.	At the time of cementation.	Immediately following cavity preparation.
Base lining, filling of undercuts.	Conventional glass-ionomer. GIC or luting cement.	Compomers or composites.
Provisionalization.	Cemented self-curing acrylic resin.	Soft light-curing resin.
Adhesive cement.	Midway-filled and low viscosity dual-cure composites.	Highly filled and high viscosity. Dual- or light-curing composites.
Restoration insertion.	Manually assisted.	Manually and ultrasonic-assisted.
Luting cement removal.	Problematic.	Convenient.

polymerization of luting composite by means of single light activation, however, is dependent on the thickness and opacity of the restorative material.[51,52] The clinical application of thick and opaque masses in the restoration base should not be utilized with single light-curing activation. The placement of a base lining may enhance the creation of optimal conditions for this new luting concept. Use of a powerful light-curing system and sufficient irradiation time (60 seconds on each restoration surface) are mandated in these specific clinical circumstances.

Practical Considerations

In clinical conditions, the removal of excess luting composite is arguably the most critical step of the cementation procedure. The challenging task for the clinician is to avoid overhangs or underhangs resulting from cementation. Margins providing a satisfactory continuity between the restoration and the tooth can be obtained only in perfectly fitting restorations.[8] The use of a highly filled and viscous composite (restorative or dual-cure cement) for luting the restoration has obvious advantages over conventional, dual, or chemically curing cements, since they do not flow over all surfaces and are cleanly removed with a probe or floss (Figures 19 through 21). Restorative materials have the important advantage of providing a convenient working time, under the control of the operator.

Conclusion

The clinical challenges associated with conventional luting materials and techniques were threefold — the lack of suitable base lining materials, the biological consequences of postponing adhesive procedures and maintaining unprotected dentin surfaces during provisionalization, and the several practical and clinical disadvantages resulting from the use of low-viscosity and chemical curing adhesive cements. The current approach in luting tooth-colored restorations (Table 2), based on the application of a flexible adhesive base lining and immediate dentin sealing, has improved the safety and predictability of the procedure, avoiding numerous potential clinical complications, such as postoperative sensitivity, fastidious removal of cement excesses, and rapid wear of the luting material. When applied in conjunction with advanced luting materials, the incremental layering of adhesive materials provides a predictable approach for the restoration of the posterior dentition.

Figure 18. Postoperative view following cementation of the semidirect composite onlay. This technique is more prone to postoperative sensitivity.

Figure 19. A ceramic onlay, ready for the adhesive cementation on a mandibular molar.

Figure 20. The flow of conventional dual curing resin cements complicates the luting procedures and the removal of excess cement.

Figure 21. Postoperative view of definitive restoration following finishing and polishing procedures.

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Continuing Education (CE) Exercise No. 2

2
CONTINUING EDUCATION

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

The 10 multiple-choice questions for this Continuing Education (CE) exercise are based on the article "Current clinical concepts for adhesive cementation of tooth-colored posterior restorations" by Didier Dietschi, DMD, and Roberto Spreafico, MD, DDS. This article is on Pages 47-54. Answers for this exercise will be published in the May 1998 issue of **PPAD.**

Learning Objectives:

This article reviews the most recent concepts in luting procedures and materials and describes an innovative concept of the utilization of restorative adhesives. Upon reading and completion of this exercise, the reader will have an:

- Up-to-date knowledge of the use of adhesive materials.
- Improved ability to effectively treat posterior dentition.

1. The adhesive luting of tooth-colored posterior restorations has long been considered a sensitive and unreliable clinical procedure due to:

a. The properties of former base lining materials.
b. The absence of an effective seal during provisionalization.
c. The use of less than optimal adhesive systems and luting cements.
d. All of the above.

2. The earlier bonding procedures were performed:

a. Just prior to cementation.
b. Following the tooth preparation.
c. Following impression taking.
d. None of the above.

3. Postoperative sensitivity is NOT known to be the symptom of:

a. Hydrodynamic phenomena.
b. System of restorative material utilized.
c. Bacterial contamination.
d. None of the above.

4. The indirect approach requires that the cavity has a proper design, with:

a. Taper.
b. Maximal undercuts.
c. Subgingival margins.
d. No base application.

5. The role of elastic layer in the base of the restoration can be assumed by the:

a. Hybrid layer.
b. Bonding resin.
c. Soft base liner.
d. Any of the above.

6. Flowable composites are an interesting option as a base lining, due to:

a. Higher modulus of elasticity.
b. Acceptable compressive strength.
c. Decreased flexibility.
d. All of the above.

7. The current approach in adhesive restorations is based on the:

a. "Progressive flexibility" concept.
b. "Reduced flexibility" concept.
c. "Sustained flexibility" concept.
d. None of the above.

8. Under general clinical conditions, the "wall-to-wall contraction" of the composite resin is:

a. Unaffected by its thickness.
b. Proportional to its thickness.
c. Disproportional to its thickness.
d. None of the above.

9. According to the published material cited by the authors, it is known that luting composites undergo more extensive wear than the restorative composites, and that occlusal wear is proportional to the interfacial gap.

a. True.
b. False.

10. According to the authors, with thick and opaque masses in the restoration base, luting composite should be cured with powerful light curing systems and a sufficient irradiation time of:

a. 40 seconds.
b. 50 seconds.
c. 60 seconds.
d. None of the above.