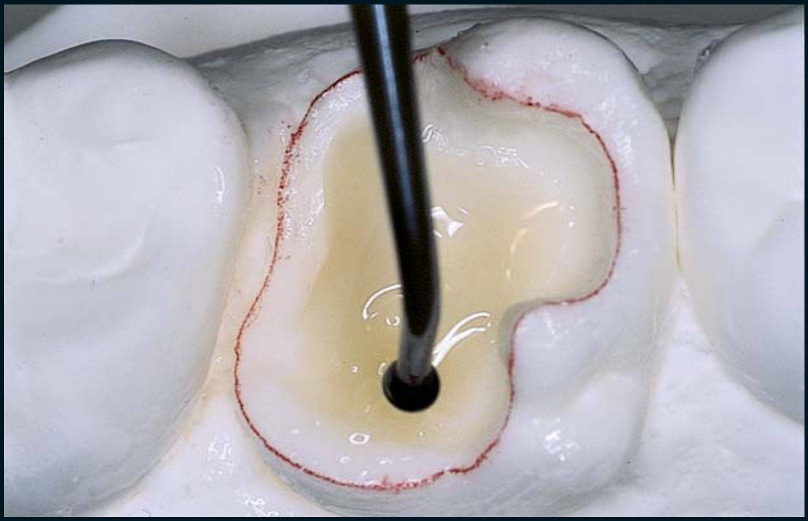
Developing Form, Function, and Natural Aesthetics With Laboratory-Processed Composite Resin—Part I

Douglas A. Terry, DDS* • Karl F. Leinfelder, DDS, MS† • Chuck Maragos, CDT‡



The metallic restorative materials of the past required the dentist to focus on function and form because metal had no tooth-colored properties. The development of tooth-colored restorative materials has introduced a new element in the restorative equation—color. Unfortunately, many clinicians continue to apply a "metallic mentality" to restorative techniques with the newer adhesive restorative materials that can produce a tooth-colored appearance. With advances in material sciences and adhesive technology, the restorative concept now includes aesthetics as a variable in the restorative equation as well.

Learning Objectives:

This article highlights the use of indirect composite resin restorations for the conservative treatment of posterior teeth. Upon reading this article, the reader should:

- Gain an awareness of the treatment planning and preparation considerations associated with laboratory-fabricated resin restorations.
- Increase his or her familiarity with the indications and material properties of indirect resin systems.

Key Words: indirect, resin, composite, posterior, shade

Assistant Professor, Department of Restorative Dentistry and Biomaterials, University of Texas Health Science Center Dental Branch, Houston TX; Faculty member, UCLA Center for Esthetic Dentistry, Los Angeles, CA; private practice, Houston, TX.

† Adjunct professor, Biomaterials Clinical Research, University of North Carolina, Chapel Hill, NC; Professor Emeritus, University of Alabama School of Dentistry, Birmingham, AL.

‡ Laboratory technician and owner, Valley Dental Arts, Stillwater, MN.

Douglas A. Terry, DDS, 12050 Beamer, Houston, TX 77089
Tel: 281-481-3470 • E-mail: dterry@dentalinstitute.com

Today, the primary goal of aesthetic dentistry is to achieve beautiful, natural restorations of the teeth that will maintain function and ensure their structural and marginal integrity,[1] while eliminating the appearance of metal such as gold and amalgam.[2] As patients seek conservative treatment that is biocompatible, durable, safe, and aesthetic,[3] increased utilization of composite resin materials for the direct restoration of the posterior dentition has drawn more attention to technological advances in the field. While new direct composite resin systems offer excellent physical and mechanical properties, their use in posterior regions should be limited to smaller restorations since polymerization shrinkage is more severe in larger cavity preparations.[4,5] Shrinkage stresses that exceed bond strength may subsequently result in a loss of adhesion at the tooth-restoration interface, increasing the likelihood of microleakage, postoperative sensitivity, and recurrent caries.[6]

Indirect composite resin and porcelain systems represent alternative restorative solutions for these larger posterior cavities. Laboratory-processed inlays fabricated with porcelain or composite resin restore mechanical and biological function while achieving optimal aesthetics with minimal tooth reduction. A conservative preparation design can be utilized, as the involved adhesive procedure strengthens the cusps and provides additional support for the dentition. Additionally, both porcelains and indirect resins provide precise marginal integrity, ideal proximal contacts, wear resistance, reduced polymerization shrinkage, and optimal aesthetics.[1,7] These restorative systems complement and broaden the scope of restorative alternatives that are available to assist the patient, technician, and dentist in making an informed selection for different clinical situations.[7]

Next-Generation Indirect Systems

Second-generation indirect systems maintain a higher density of inorganic ceramic microfillers compared to the earlier-generation direct and indirect systems.[8] These materials have been noted for possessing the advantages of composite resins and porcelains without being confined by their inherent limitations.[9]

The biomaterials known as “microhybrids” include a combination of inorganic particles (fillers) and an organic polymer (matrix) with a filler content that contains twice the organic matrix content (approximately 66% inorganic fillers and 33% resin matrix). The filler is the primary determinant of the clinical and physiochemical properties of the composite resin. These submicron-particle fillers demonstrate exceptional surface characteristics such as polishability and wear resistance.[10] The wear is influenced by the size, shape, load, and matrix bonding of the filler.[11-13] In fact, a significant reduction in wear resistance has been obtained by decreasing the size of the filler particle.[11,14]

Newer resin formulations of varied size, shape, composition, and concentration have significantly enhanced mechanical characteristics that have been achieved by reducing their polymerization shrinkage, while increasing the flexural and tensile strength, the resistance to abrasion and fracture, and color stability.[15,16] Several of the next-generation indirect resin composites that possess these characteristics are belleGlass NG (Kerr/Sybron, Orange, CA), Sculpture Plus (Jeneric/Pentron, Wallingford, CT), Gradia Light-Cure (GC America, Alsip, IL), and Tescera ATL (Bisco, Schaumburg, IL).

The various methods of postcuring (eg, light, heat, pressure, vacuum, nitrogen) allow for secondary curing of the composite by increasing the conversion of the material from monomer to polymer.[15] This heightened but controlled degree of polymerization increases fracture toughness, flexural and diametral tensile strength, wear resistance, incisal edge strength, and color stability.[17,18]

Figure 1. Preoperative occlusal view of a defective amalgam restoration with a fractured buccal cusp and recurrent decay on the maxillary left first molar.

Figure 2. After elimination of the amalgam restoration, the rubber dam is removed and shade selection is performed before completion of the preparation.

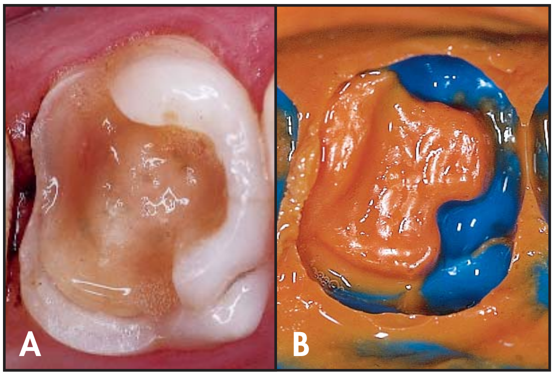


Figure 3A. Occlusal view of completed preparation design. Figure 3B. A polyvinylsiloxane impression is made of the preparation.

Figure 4. A thin layer of separator is applied to the die to act as a separating medium and die spacer.

This article demonstrates the development of a posterior onlay that employs a new indirect laboratory composite resin system (ie, belleGlass NG, Kerr/Sybron, Orange, CA) utilizing a heat-curing process in conjunction with nitrogen pressure.

Preoperative Considerations

A 55-year-old male patient presented with defective amalgam restoration with a fractured buccal cusp and recurrent decay on the maxillary left first molar (Figure 1). The patient expressed interest in replacing the existing amalgam restoration with the most conservative and aesthetic restoration available. Before establishing the parameters of the cavosurface boundaries of the preparation design, it was necessary to evaluate the mesiolingual fissure at the cusp of Carrabelli with light-induced fluorescence (ie, DIAGNodent, KaVo, Lake Zurich, IL). This device, which aided in the assessment of caries, had a reading of 9 that indicated the absence of caries and, therefore, the region should be monitored.

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 or digital camera, and reviewed on a stone model. This initial registration was valuable in preparation design, when considering the placement of centric stops beyond or within the confines of the restoration, and in minimizing finishing procedures.[19] A preoperative selection of composite resins and tints and modifiers with their shade and orientation was recorded.

Preparation, Impression, and Provisionalization

At the first clinical appointment, the amalgam restoration was removed under rubber dam isolation. The rubber dam was then removed and shade selection and photographic comparison were performed prior to completion of the preparation because an elevated value and/or the selection of an improper shade could result from tooth dehydration and elevated values (Figure 2).[20] A shade map or restorative recipe was used to diagram the existing colors of the tooth to be prepared and indicated anatomic morphological details (eg, developmental grooves, shape of embrasures, prominences, convexities, facets) or any other characteristics that provided helpful information for the tooth surfaces being reconstructed.[21] The tooth was again isolated with a rubber dam to protect against contamination, facilitate moisture control, and to achieve adequate field control. A caries-disclosing solution was applied to the internal surfaces of the preparation to facilitate detection and identification of the irreversible infected carious tissue and to serve as a guide for its removal.[22]

The adhesive preparation design preserved sound tooth structure and required no extension for prevention. The preparation was limited to access to the defect, since the composite required less volume to resist clinical fracture than would have an amalgam.[23,24] Upon removal of the existing recurrent caries, the cavity design followed the preparation guidelines for indirect onlay restorations (Figure 3A): all enamel supported by sound dentin, all internal angles and edges rounded, isthmus width of at least 2 mm with a depth of at least 1.5 mm, all proximal walls flared or diverged 5 to 15 degrees with no undercuts, sharp cavosurface margins, and the gingival margins prepared to a 90-degree cavosurface line angle (ie, butt joint) with no feather-edge preparation.[1,9,15] 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 of tooth flexure, thinner areas of tooth structure may be judiciously inlayed. For large restorations

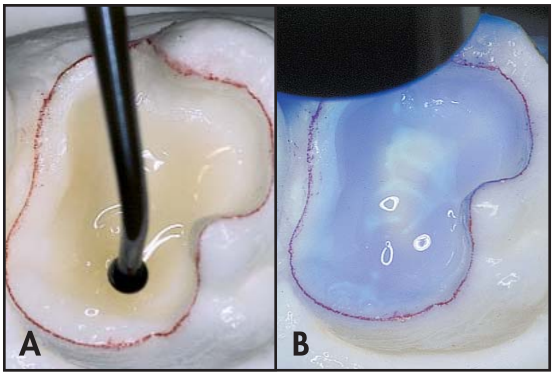


Figure 5A. An A2-shaded flowable resin is injected and uniformly distributed with a ball-shaped instrument. Figure 5B. The flowable composite is light cured for 40 seconds.

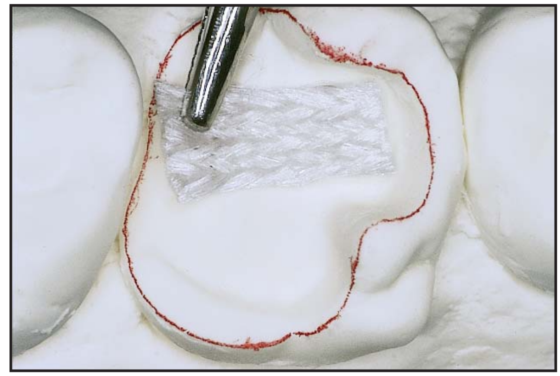


Figure 6. Prior to application of the flowable resin, the preparation's dimension is measured for the placement of the fiber reinforcement.

or weak teeth with minimal enamel, fibers should be included as a base on which to veneer the composite.[9]

Prior to impression taking, it was important to seal the dentin tubules with a hybrid layer.[7,15] This protected the pulp from the invasion of microorganisms and reduced sensitivity during the provisional stage. Once the preparation was conditioned, a thin layer of adhesive (ie, Optibond Solo Plus, Kerr/Sybron, Orange, CA) was applied on the preparation surfaces with an applicator for 20 seconds, air thinned for 5 seconds, and light cured for 20 seconds. A polyvinylsiloxane impression (ie, Take 1, Kerr/Sybron, Orange, CA; Aquasil, Dentsply Caulk, Milford, DE; Imprint II, 3M Espe, St. Paul, MN; Splash, Discus Dental, Culver City, CA) was made, including all cavosurface margins (Figure 3B). A direct provisional restoration was placed with a matrix band using a light-cured, semi-flexible material (ie, Fermit, Ivoclar Vivadent, Amherst, NY), and the occlusion was inspected.

Figure 7. An A2-shaded opacious dentin layer is placed in the center of the preparation.

Figure 8. The premeasured reinforcement fiber is pulled through the unfilled resin.

Laboratory Fabrication

Upon review of the clinical photographs and color diagram, a die stone was mixed in the correct powder/liquid ratio under vacuum, and the impression was poured for a master cast and a working cast. The casts were mounted on an articulator for the duplication of occlusal movements. The working model was mounted on dies to facilitate the layering process. An A and B silicone separator was applied to the cavity and to any part of the model that would contact the composite resin, and was air dried (Figure 4). This layer acted as a separating medium and die spacer. As an initial step in the buildup procedure, an A2-shaded flowable composite (ie, Revolution II, Kerr/Sybron, Orange, CA) was injected, as the syringe tip was slowly removed, and uniformly distributed. A thin layer (ie, 0.1 mm to 0.2 mm) was applied to the pulpal floor of the Class I cavity and the increment was light cured for 40 seconds (Figure 5). This "connective layer" was thin in order to limit the polymerization shrinkage.[15] Because of their low modulus, these composites acted as an elastomer and buffered the polymerization shrinkage stress by flow, thus preventing detachment of the resin from the stone.[25] This layer minimized the formation of voids and also prevented the subsequently incorporated fibers from being

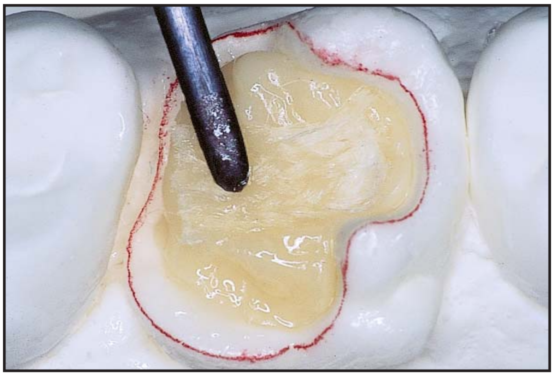


Figure 9. The reinforcement fiber is completely coated with unfilled resin and adapted into the soft initial opacious dentin layer.

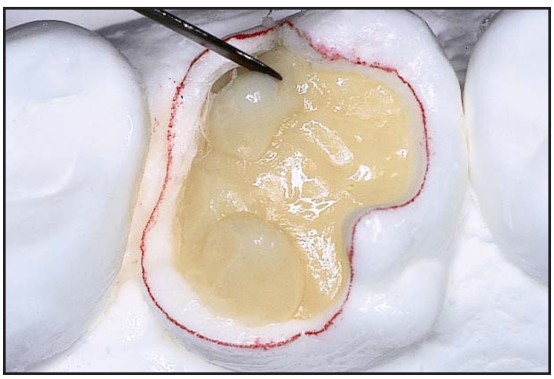


Figure 10. Subsequent increments of opacious dentin are placed to develop the cusp and incline planes.

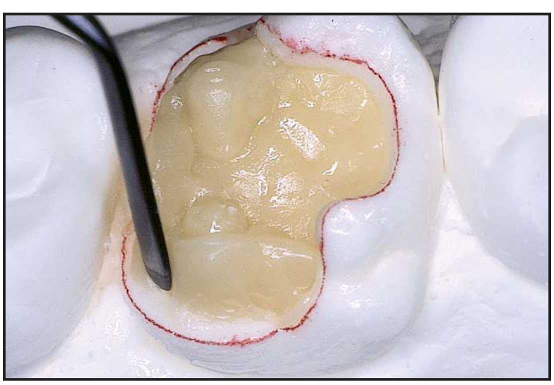


Figure 11. Using a long-bladed composite instrument, the internal dentin core is contoured.

exposed during surface treatment, which could have caused tissue irritation, water absorption, color change, and potential delamination of the material.

The Artificial Dentin Core

The preparation's dimension was previously measured in a mesiodistal direction for the placement of fiber reinforcement (Figure 6). To support the composite resin,

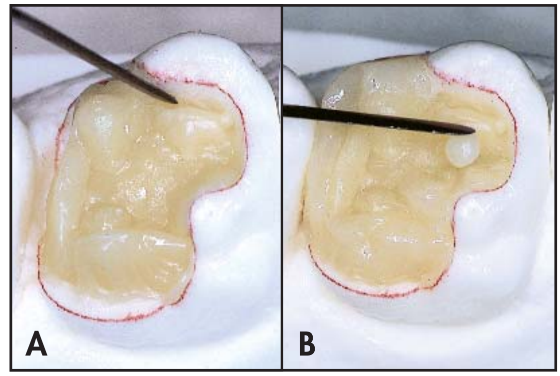


Figure 12A. The internal dentin core is developed.12B. An A-2 shaded translucent composite increment is placed and shaped around the dentin core.

additional fibers were integrated into the resin matrix[9,26] during fabrication and before the curing process. These fibers were surface-treated to enhance their adhesion to the synthetic restorative material.

In order to integrate layers of different color and opacity, an opacious A2-shaded composite was placed as the initial "artificial dentin" layer in the center of the preparation, identifying the position of the central groove and cusp division (Figure 7). The premeasured reinforcement fiber was worked through the resin until it was coated and incorporated into the uncured dentin layer and light cured for 40 seconds (Figures 8 and 9). The flexural strength and fracture resistance of the restoration would be increased by the addition of these composite-reinforced fibers,[9] which would help reduce fractures in this region of increased occlusal stress. The reinforcement fibers were internally adapted to the initial dentin layer.

The selection of an opacious dentin (ie, belleGlass NG, Kerr/Sybron, Orange, CA) allowed the fibers to be completely disguised. Subsequent increments of opacious dentin were placed to develop the cusps and incline planes, shaped, and smoothed with a #4 artist's sable brush (Figure 10). Modeling gel was applied to the tip of the brush to reduce surface tension, enhance adaptation, and reduce the possibility of entrapping bubbles that could have interfered with the placement of tints for internal characterization. The internal dentin core was developed by placing additional opacious A2-shaded composite in a circumferential pattern around the center core. It was important to observe the required boundaries of the artificial enamel layer and not trespass into this zone. An indentation was developed around this central dentin core with a long-bladed instrument (ie, TNCVIPCL, Hu-Friedy, Chicago, IL) to allow a subsequent placement of translucent dentin into this region and to integrate layers of different colors and opacities

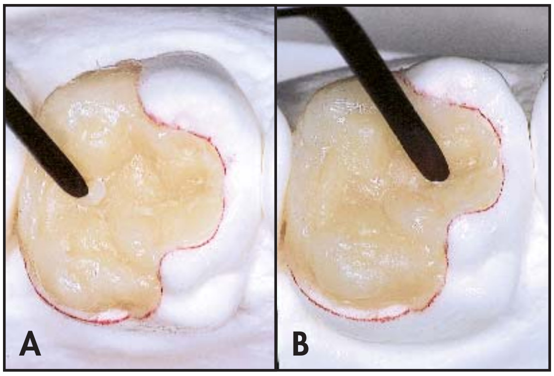


Figure 13A. Translucent C1-shaded composite increments are placed on the occlusal planes and between the dentin core and the tooth structure. 13B. An invagination is defined with a long-bladed instrument forming a central, lingual, and a buccal groove.

(Figure 11). An increment of translucent A2-shaded composite was applied according to the shade mapping diagram. Each increment was placed, contoured around the existing dentin core, and light cured for 40 seconds (Figure 12).

Translucent C1-shaded composite increments were placed on the occlusal planes and into the previously formed invagination between the dentin core and the tooth structure (Figure 13). Each increment was placed with a long-bladed instrument, contoured, and shaped with a curved instrument (ie, TINL-R, Brasseler USA, Savannah, GA); the anatomical contours were developed incrementally and smoothed with a #4 artist's sable brush. Additional increments of translucent A2-shaded composite were placed along the incline ridges and smoothed as well.

Conclusion

Clinicians can now integrate the existing restorative concepts of function and form with a knowledge of color and anatomical morphology to create natural tooth-colored restorations. The technician and clinician should integrate these restorative concepts with the process of working from the inside to the anticipated final result on the outside. Whereas part one of this article has reviewed the material composition of contemporary indirect resin systems and provided a detailed description of the preparation of an onlay restoration, part two will complete its laboratory fabrication, surface preparation, cementation, and finishing. Although the long-term benefits of this next-generation resin formulation remains to be determined, when proper laboratory and clinical techniques are combined with the physical and optical properties of these new materials, the result can be indistinguishable from natural dentition.

References

1. Howard NY. Advanced use of an esthetic indirect posterior resin system. Compend Contin Educ Dent 1997;18(10):1044-1046, 1048, 1050.
2. Touati B. Bonded ceramic restorations: Achieving predictability. Pract Periodont Aesthet Dent 1995;7(4):33-37.
3. Neumann LM, Christensen C, Cavanaugh C. Dental esthetic satisfaction in adults. J Am Dent Assoc 1989;118(5):565-570.
4. Bausch JR, de Lange K, Davidson CL, et al. Clinical significance of polymerization shrinkage of composite resins. J Prosthet Dent 1982:48(1):59-67.
5. Bouschlicher MR, Vargas MA, Boyer DB. Effect of composite type, light intensity, configuration factor and laser polymerization on polymerization contraction forces. Am J Dent 1997;10(2): 88-96.
6. Davidson CL, de Gee AJ, Feilzer A. The competition between the composite-dentin bond strength and the polymerization contraction stress. J Dent Res 1984;63(12):1396-1399.
7. Touati B, Aidan N. Second generation laboratory composite resins for indirect restorations. J Esthet Dent 1997;9(3):108-118.
8. Douglas RD. Color stability of new-generation indirect resins for prosthodontic application. J Prosthet Dent 2000;83(2):166-170.
9. McLaren EA, Rifkin R, Devaud V. Considerations in the use of polymer and fiber-based indirect restorative materials. Pract Periodont Aesthet Dent 1999;11(4):423-432.
10. 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 and Manufacturing Co; 1985:139-159.
11. 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.
12. Braem M, Finger W, Van Doren VE, et al. Mechanical properties and filler fraction of dental composites. Dent Mater 1989;5(5):346-348.
13. St. Germain H, Swartz ML, Phillips RW, et al. Properties of microfilled composites resins as influenced by filler content. J Dent Res 1985;64(2):155-160.
14. Bayne SC, Taylor DF, Heymann HO. Protection hypothesis for composite wear. Dent Mater 1992;8(5):305-309.
15. Miara P. Aesthetic guidelines for second-generation indirect inlay and onlay composite restorations. Pract Periodont Aesthet Dent 1998;10(4):423-431.
16. Olk C. Esthetics in the composite resin veneer technique. Quint Dent Tech 2000;23:159-167.
17. Cook WD, Johannson M. The influence of postcuring on the fracture properties of photo-cured dimethacrylate based dental composite resin. J Biomed Mater Res 1987;21(8):979-989.
18. Bausch JR, de Lange C, Davidson CL. The influence of temperature on some physical properties of dental composites. J Oral Rehab 1981;8(4):309-317.
19. Liebenberg WH. Successive cusp build-up: An improved placement technique for posterior direct resin restorations. J Can Dent Assoc 1996;62(6):501-507.
20. Fahl N, Denehy GE, Jackson RD. Protocol for predictable restoration of anterior teeth with composite resins. Pract Periodont Aesthet Dent 1995;7(8):13-21.
21. Baratieri LN, Monteiro Junior J, de Andrada MA, Aracari GM. Composite resin veneers: A new technique. Quint Int 1992; 23(4):237-243.
22. Kidd EA, Joyston-Bechal S, Beighton D. The use of a caries detector dye during cavity preparation: A microbiological assessment. Br Dent J 1993;174(7):245-248.
23. Roberson TM, Heymann HO, Swift J. Sturdevant's Art and Science of Operative Dentistry. St. Louis, MO: Mosby-Year Book; 1995.
24. Leinfelder KF. A conservative approach to placing posterior composite resin restorations. J Am Dent Assoc 1996;127(6): 743-748.
25. Prager MC. Using flowable composites in direct posterior restorations. Dent Today 1997;16(7):62,64-69.
26. Leinfelder KF. New developments in resin restorative systems. J Am Dent Assoc 1997;128(5):573-581.

CONTINUING EDUCATION (CE) EXERCISE NO. X

X
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, "Developing form, function, and natural aesthetics with laboratory-processed composite resin—Part I," by Douglas A. Terry, DDS, Karl F. Leinfelder, DDS, MS, and Chuck Maragos, CDT. This article is on pages ###-###.

1. Shrinkage stress can result in a loss of adhesion at the tooth-restoration interface and can increase the potential for the following:
a. Recurrent caries.
b. Postoperative sensitivity.
c. Microleakage.
d. All of the above.

2. The various methods that allow for secondary curing of the composite include:
a. Light.
b. Heat and nitrogen
c. Vacuum.
d. Pressure.
e. All of the above.

3. The preparation guidelines for an indirect onlay restoration include the following:
a. Gingival margins prepared to a 90-degree cavosurface line angle.
b. All enamel supported by sound dentin.
c. All internal angles and edges should be sharp not rounded.
d. Both a and b.
e. All of the above

4. The flexural strength and fracture resistance of the laboratory-processed composite restorations can be increased by the addition of composite-reinforced fibers. This addition of reinforcement fibers can help to reduce fractures in regions of increased occlusal stress.
a. The first statement is correct and the second statement is incorrect.
b. Both statements are correct.
c. The first statement is incorrect and the second statement is correct.
d. Both statements are incorrect.

5. Clinical benefits seen with laboratory-processed inlays fabricated with porcelain or composite resin include the following:
a. Tooth reinforcement.
b. Ideal proximal contacts.
c. Optimal aesthetics.
d. All of the above.
e. Both a and c.

6. Internal characterizations within the indirect composite restoration can emphasize the following:
a. Tooth form.
b. Depth and a three-dimensional effect.
c. Both a and b.
d. None of the above.

7. The wear of the composite resin restoration is influenced by all but one of the following:
a. Size of the filler.
b. Load of the matrix.
c. Shape of the filler.
d. Matrix bonding of the filler.
e. a, c, and d.

8. Purging oxygen out of the system in cycles and replacing with nitrogen provides the following:
a. Eliminates the air-inhibition layer.
b. Reduces microleakage.
c. Allows for a more complete polymerization.
d. Both a and c.
e. All of the above.

9. Composite materials have shown a greater capacity to absorb compressive loading forces and reduce the impact forces by 57% more than porcelain. Composites transmit less of the applied load to the underlying tooth structure.
a. The first statement is correct and the second statement is incorrect.
b. The first statement is incorrect and the second statement is correct.
c. Both statements are correct.
d. Both statements are incorrect.

10. Composite inlays have excellent marginal integrity because of the similar thermal expansion rate as the luting cement. The similarity in coefficients of thermal expansion for porcelain inlays and the composite luting cement can result in an increased width of luting gap.
a. The first statement is correct and the second statement is incorrect.
b. The first statement is incorrect and the second statement is correct.
c. Both statements are correct.
d. Both statements are incorrect.