THE ADHESIVE DESIGN CONCEPT

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Advances in restorative material formulations and adhesive technology have expanded and created new treatment possibilities for dental practitioners. Due to this evolution, composite resins are being used with increasing frequency in posterior restorations. In order to successfully place these restorations, the clinician must understand the rationale for restorative material selection, preparation design, adhesive protocol, and composite resin placement. This article illustrates these considerations for placing a Class I posterior composite restoration.

Learning Objectives:

This article discusses a conservative design that is appropriate for the utilization of modern microhybrid resins. Upon reading this article, the reader should:

- Have a thorough understanding of modern adhesive procedures to achieve long-term success with composite resin restorations.
- Identify the factors that influence polymerization shrinkage, the effects of shrinkage stress, and methods to overcome these limitations.

Key Words: adhesive, composite resin, preparation, microhybrid

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In recent years, there have been dramatic changes in clinicians' understanding and control of the caries process, with a reduction in the incidence and severity of caries and in the means of detecting decay with chemical agents. This has led the author to reconsider traditional restorative principles, many of which have become dated. *The principle of extension for prevention* has yielded to an *adhesive preparation design*, a more conservative approach to tooth preparation.[1,2] Traditional methods for discerning decay from stained tooth structures have been supplemented with innovations such as caries-detecting agents, improved illumination, and optical aids, which are used to enhance the clinician's diagnostic skills.[3]

Unfortunately, many clinicians continue to perform outdated procedures with modern restorative materials, and then wonder why they continue to have microleakage, recurrent decay, and sensitivity. The effect of this misdirection could be one of the reasons for the relatively short clinical service of composite restorations in the general dental practice.[1] Advances in material science and adhesive technology require the clinician to modify his or her nonadhesive restorative techniques when placing adhesive restorations. This is particularly true when one is considering diagnosis, material selection, preparation design, restorative placement techniques, pulp protection finishing, and maintenance.[2] The adhesive design concept requires the selection of adhesive, bioactive restorative materials, simplified modifications of preparation designs, and precise placement procedures and techniques. This design concept has been instrumental in the paradigm shift from the principles of extension for prevention to prevention to eliminate extension.

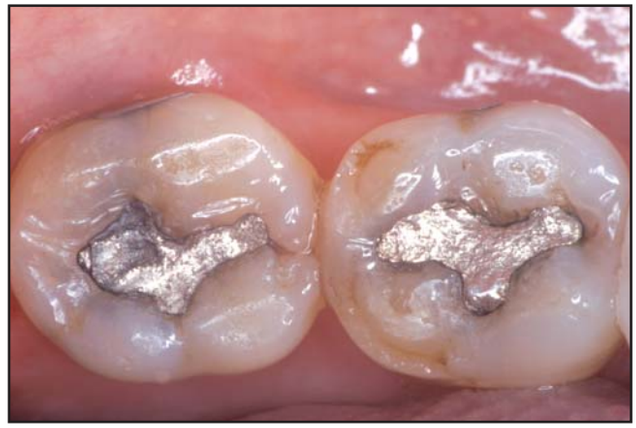

Figure 1. Preoperative occlusal view of defective amalgam restorations with recurrent decay was determined by differential diagnosis (eg, sensitivity, radiographic review).

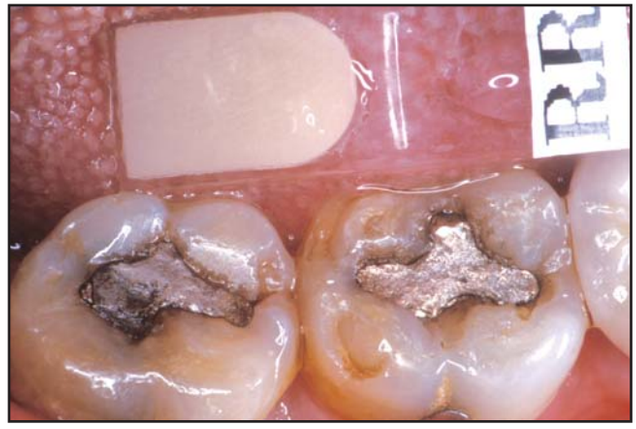

Figure 2. Shade selection was performed before placement of the dental dam using the Venus 2Layer shade system (Heraeus Kulzer, Armonk, NY).

Restorative Material Selection

When selecting a restorative composite resin, the average filler particle size, filler loading, and particle size distribution provide information about the most appropriate use of the composite resins. In the past, the dilemma in choosing either the hybrid or the microfill composite resin often required the use of a combination of both to achieve a restorative result with optimal physical and mechanical characteristics.

The development of the polychromatic restoration from the different types of composite resin (eg, hybrid, microfill) led clinicians and manufacturers to explore restorative materials that are not only applied in relation to the natural tissue anatomy, but also those possessing properties similar to tooth structure.

Newer formulations of smaller particle hybrid composite resins (eg, Venus, Heraeus Kulzer, Armonk, NY; Filtek Supreme, 3M ESPE, St. Paul, MN) represent the variations in particle size, shape, and orientation that enhance their physical, mechanical, and optical characteristics.[4] This provides the clinician with restorative materials that can be sculpted and have high fracture strength, good color stability, and durability of polish.[5] Thus, stratifying microhybrid resins requires the clinician only to consider the intended outcome during diagnosis and treatment planning and not the particular region on the tooth or restoration, as was often necessary with the hybrid and microfill layering process. Clinicians, therefore, need only consider the color parameters when devel-

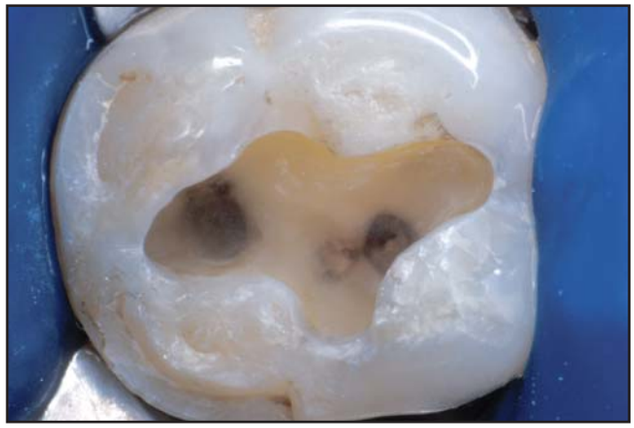

Figure 3. View of the completed preparation.

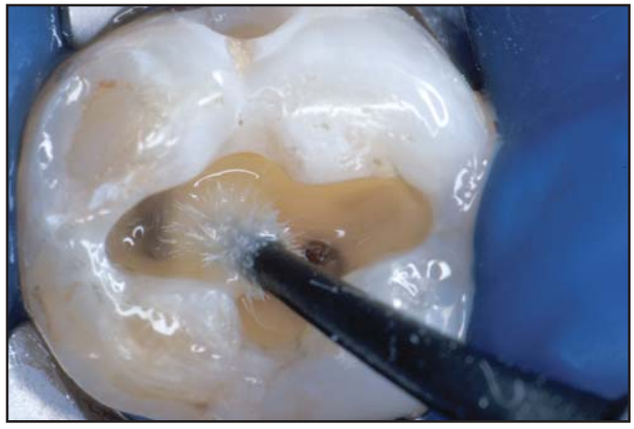

Figure 4. After application of a 32% phosphoric acid semigel etchant (ie, UNI-ETCH, Bisco, Schaumburg, IL) and rinsing with water for 15 seconds, a single-component adhesive (ie, Gluma Comfort Bond+ Desensitizer, Heraeus Kulzer, Armonk, NY) was applied.

oping the proper form and aesthetics of the restoration.

In addition, the adhesive application of newer formulations of microhybrid resins permits a conservative design (Figures 1 through 3). This is based upon the material selection being limited to a single restorative material—a universal microhybrid composite—that has enhanced physical, mechanical, and optical characteristics similar to the natural tooth structure.[5,6] Therefore, it is not necessary to compensate for fracture resistance of the restoration by increasing the volume of restorative material at the restorative interface through tooth preparation as would be required of a stratification technique using a hybrid and a microfill. Additionally, in clinical situations that do not require increased space parameter considerations for optical integration of color (ie, utilization of the natural color of the dentin), a more conservative preparation will allow the elimination of an additional layer of microfill for the enamel layer, since these microhybrids have improved polishability and durability of polish.[7,8]

Adhesive Preparation Design

Composite resin restorations utilize adhesive cavity preparation designs.[9,10] Consideration should be given to tooth type (ie, molar, bicuspid, incisor) as well as to the location, size, and type of the carious lesion. Other considerations should include treatment of decayed or nondecayed, unrestored teeth or restoration replacement. The clinician should also evaluate the relationships between occlusal function and preparation boundaries in order to facilitate the placement of centric stops beyond or within the confines of the restoration. Final considerations should be made for the type of restorative technique, the quantity and quality of the remaining tooth structure and the mechanical forces exerted on it, the presence of defects, and the parameters for extension of the preparation to the aesthetic zone.[11]

The following general guidelines should be followed for initial or replacement restorations for the Class I direct composite resin preparation:

- Carious dentin can be removed using slow- and high-speed carbide burs and spoon excavators. The preparation is limited to access to the lesion or defect, since composites require less volume to resist clinical fracture than amalgam;[12]
- The occlusal outline should eliminate all carious enamel, provide access to the carious dentin, eliminate any residual amalgam staining, and provide access for the application of the restorative materials;
- The width of the preparation should be as narrow as possible, since the wear of the restoration is a direct function of dimension.[2] Additionally, the increased buccolingual width of the preparation can trespass into the centric holding areas;
- Healthy tooth structures should only be removed when the occlusal outline requires extension beyond or within the previously indicated functional stops;
- The occlusal cavosurface margin should not be beveled since it increases the width of the preparation and may infringe upon the centric holding area, increasing the wear rate of the

restoration.[2,13] If the occlusal width becomes excessive, however, a beveled occlusal surface should be considered; and

- To allow for a better resin adaptation, all internal line angles should be rounded and cavity walls should be smooth, as defined by the surface effects generated by a conventional preparation bur.[14]

Adhesive Protocol

The chemical treatment of enamel and dentin by acids to provide adhesion between resins and dentin substrates (eg, enamel, dentin) has become a standard clinical procedure in adhesive dentistry (Figure 4). The removal of the smear layer raises the surface energy and alters the mineral content of the substrate so that it can be infiltrated by subsequently placed adhesive primers and resins. The mechanism of adhesion is similar for enamel and dentin—a micromechanical entanglement of monomers into the enamel microporosities or collagen interfibrillar spaces created by acid dissolution of mineralized tissues. When evaluating restorative success, the marginal integrity achieved by this procedure becomes a priority since an intact restorative-tooth interface is essential to the exclusion of bacteria and the interfacial hydrodynamic equilibrium of the dentino-pulpal complex.

For successful bonding to dentin, one of two different adhesive protocols may be used. The total-etch protocol requires the application of acids that decalcify the surface layer of dentin. The acid removes the smear layer and opens the dentinal tubules, increases dentinal permeability, and decalcifies the intertubular and peritubular dentin. The removal of the mineralized tissues (ie, hydroxyapatite crystals) leaves a network of collagenous fibrils exposed, which overlay the deeper, decalcified dentin.[15,16]

The self-etching primer protocol concurrently removes the smear layer and infiltrates the decalcified dentin by an acidic monomer. This technique permits the simultaneous infiltration of the collagen fibers and decalcification of the inorganic component to the same depth in dentin, thus minimizing the risk of incomplete penetration of adhesive monomers into the demineralized dentin. Additionally, this prevents the collapse of the collagen fibrils that can occur after conditioning and drying in the total-etch technique. The resin may slightly

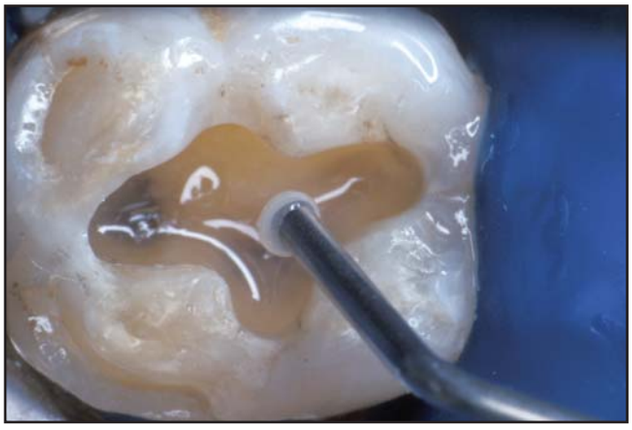

Figure 5. A B-2 shaded flowable composite (ie, Venus Flow, Heraeus Kulzer, Armonk, NY) was applied as a stress-absorbing liner between the adhesive and the resin and light cured for 40 seconds.

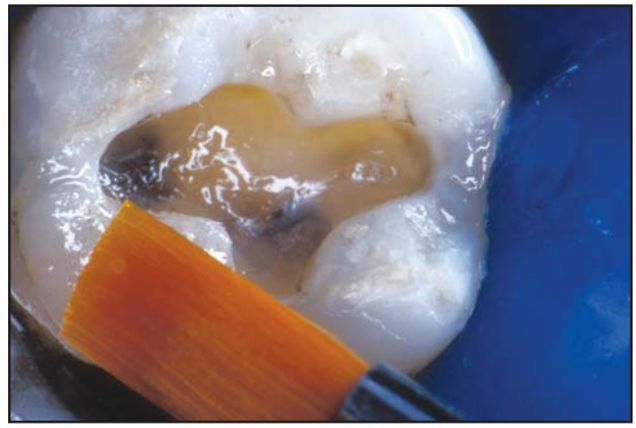

Figure 6. A B-1 shaded hybrid composite (ie, Venus, Heraeus Kulzer, Armonk, NY) was applied as a lingual enamel envelope and smoothed with a sable brush and light cured for 40 seconds.

Figure 7. Using an oblique layering technique, an opacious B-2 shaded hybrid composite (ie, Venus, Heraeus Kulzer, Armonk, NY) was applied against the opposing cavity walls and smoothed to the pulpal floor, disguising the discolored dentin, and light cured.

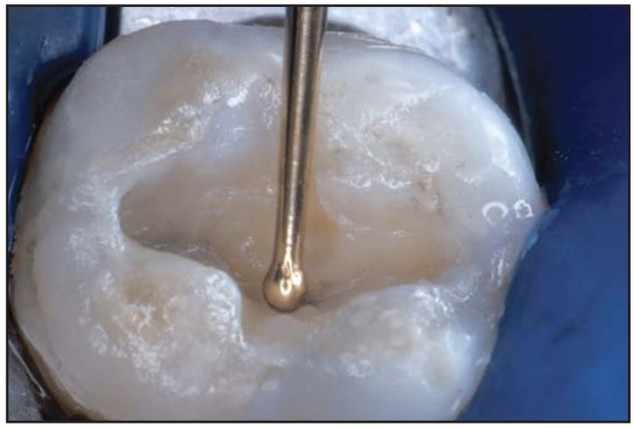

Figure 8. The microhybrid composite resin (ie, Venus, Heraeus Kulzer, Armonk, NY) was applied using a ball-tipped instrument; light curing was then conducted through the cusp to allow the material to shrink toward the interface, improving the marginal adaptation.

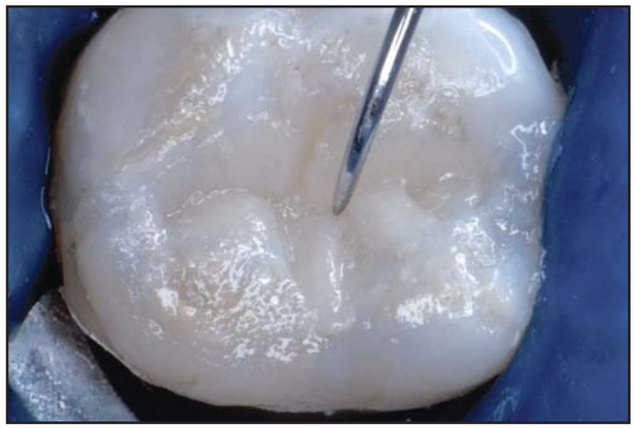

Figure 9. The first enamel layer, a B-1 shaded hybrid composite (ie, Venus, Heraeus Kulzer, Armonk, NY), was applied and sculpted with an explorer while the material was still soft.

(ie, 0.1 μm to 0.5 μm) infiltrate the smear layer and the dentin and copolymerize.[17]

Both of these adhesive protocols permit the formation of a resin-reinforced zone, (ie, the resin-infiltrated layer or hybrid layer) that is the primary bonding mechanism of many current adhesive systems[15,16] This hybridization of the exposed dentin with an adhesive system is considered by some to be the most effective way of protecting this pulp-dentin interface, and bonding the composite resin to the tooth structure provides resistance to microleakage and retention of the restoration. Since the adhesive layer may absorb polymerization shrinkage stress of the resin composite by elastic elongation, hybridization allows internal adaptation for stress relief at the restorative interface between composite resin and the dentin, while eliminating sensitivity. [18,19] This results in improved marginal and interfacial adaptation with reduced gap formation.

Placement Procedures and Techniques

A fundamental requirement for successful bonding of directly placed adhesive restorations requires isolation of the tooth. The best means of moisture control is the rubber dam. Contamination of the enamel and dentin with saliva, moisture from intraoral humidity, and blood and crevicular fluid can compromise the longevity of the adhesive restorations by reducing the bond strengths and adhesion to the tooth. Numerous studies report microleakage, reduced adhesion, and bond strength reduction from contamination of enamel with saliva, moisture, and moisture contamination from crevicular fluid.[20-22]

Incremental layering also improves the operator's control of resin condensation, densification, marginal adaptation, polymerization of the restorative material, and bond formation. Additionally, stratification provides control of overhangs in the lateral margins prior to curing, reduces the effects of polymerization shrinkage, allows the orientation of the curing light beam according to the position of each composite layer, and the placement of optimal anatomical contours of the restoration.[23,24]

Many restorative techniques and innovations have been developed to overcome the limitations of deficient marginal adaptation. These include light reflecting wedges,[25] varying the position of the curing light, [25] use of condensation and polymerization tips,[26,27] and others.[28-31] Each is combined with multilayered methods

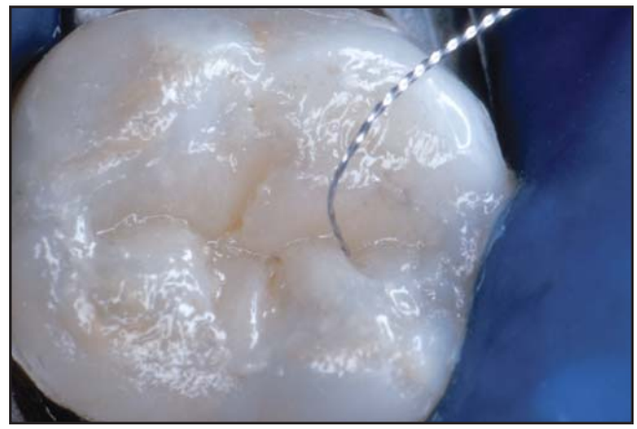

Figure 10. Brown tint (ie, Creactive Colorfluid, Heraeus Kulzer, Armonk, NY) was placed with an endodontic file into specific regions, according to the shade diagram.

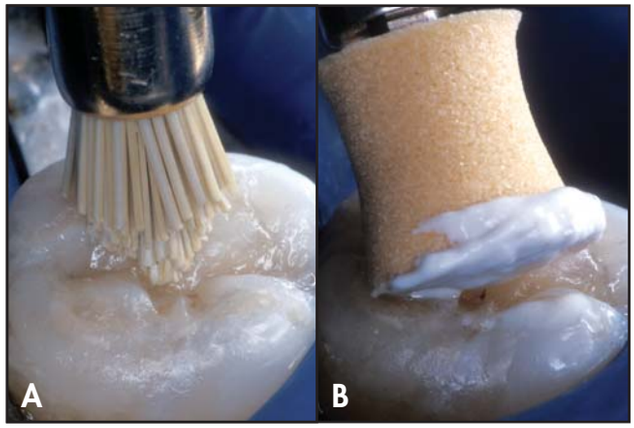

Figure 12A. The polish was completed with silicone carbide impregnated brushes. 12B. A synthetic foam cup was then used with a composite polishing paste to render the luster.

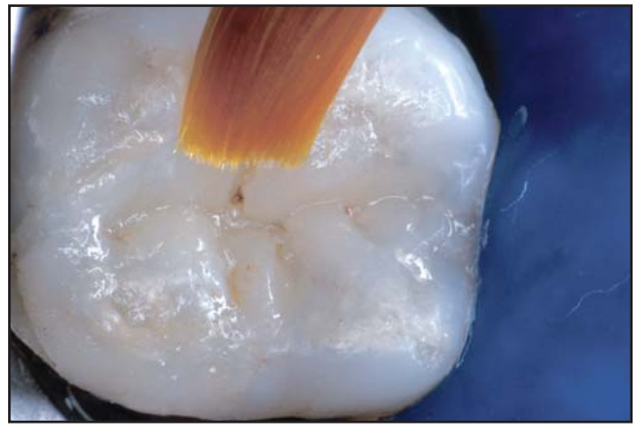

Figure 11. The final enamel layer, a translucent-shaded hybrid composite (ie, T2, Venus, Heraeus Kulzer, Armonk, NY) was sculpted to ideal anatomical contours.

(eg, horizontal, vertical, oblique, 3-sited, centripetal layering) according to the type and dimension of the cavity preparation.

Selecting the appropriate restorative placement technique requires a proper understanding of the consequences of polymerization shrinkage. Long-term success depends upon maintaining the integrity of the bond and the marginal adaptation to the tooth structure, both critical for the long-term clinical success of posterior composite restorations.[32] The polymerization shrinkage of the resin matrix phase can compromise dimensional stability.[33] The conversion of the monomer molecules into a polymer network is accompanied with a closer packing of the molecules, leading to bulk contraction.[34] If a polymerizable resin is bonded to rigid structures, bulk contraction cannot occur without increased stress, flexure, or gap formation at the adhesive interface between the resin and the tooth.[33] The shrinkage stresses are transferred to the surrounding tooth structures since they restrict the volumetric changes.[34] Some of the factors that influence polymerization shrinkage include: the type of resin, filler content of the composite[34] elastic modulus of the material, curing characteristics,[35] cavity configuration,[36] and the intensity and wavelength of the light used to polymerize the resin.[37]

Polymerization shrinkage may cause microleakage, fractures, staining, secondary caries, and postoperative sensitivity.[33,38,39] In order to minimize shrinkage stress, additional means of stress reduction can be considered when selecting restorative materials that are subject to shrinkage; liners and bases can be applied to act as shock absorbers (Figure 5),[40] selective bonding can be performed (in appropriate cavity configurations), light

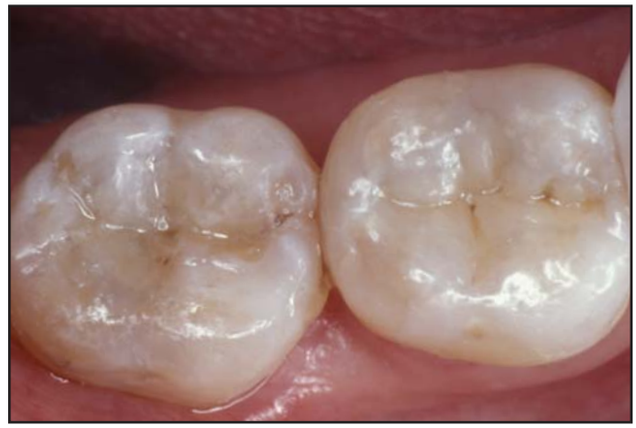

Figure 13. The postoperative result demonstrates the integrity of the bond and the marginal adaptation to the tooth structure at the restorative interface.

intensity can be reduced from curing units,[36] or a combination of selective bonding and incremental layering of small increments of composite resins will also reduce interfacial stress (Figures 6 through 13). The use of low-intensity curing-light sequences to reduce shrinkage stress controls the plasticity (flow capacity) of the restoration during curing, while the final mechanical stability of the restoration remains unaffected.[41,42]

Conclusion

The mechanical approach of the past is transforming into a biologic philosophy, strategy, and design. The adhesive design concept describes this rationale for the preparation and placement of adhesive restorations. This concept explains that the preparation design can be, and is, influenced by the selection of the restorative

biomaterial,[43] while also providing insight into the interplay between adhesion and polymerization shrinkage within these adhesive materials and how they can be influenced by placement techniques and adhesive protocols. Thus, proper selection and utilization of biomaterials with thorough and accurate adhesive protocols and precise placement techniques can directly influence the longevity of these restorations. As the industry continues to develop improved methods and materials, the clinician should consider using the aforementioned adhesive design concept while exploring new products and techniques.

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