Direct-Indirect Class V Restorations: A Novel Approach for Treating Noncarious Cervical Lesions

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ABSTRACT

Noncarious cervical lesions are highly prevalent and may have different etiologies. Regardless of their origin, be it acid erosion, abrasion, or abfraction, restoring these lesions can pose clinical challenges, including access to the lesion, field control, material placement and handling, marginal finishing, patient discomfort, and chair time. This paper describes a novel technique for minimizing these challenges and optimizing the restoration of noncarious cervical lesions using a technique the author describes as the class V direct-indirect restoration. With this technique, clinicians can create precise extraoral margin finishing and polishing, while maintaining periodontal health and controlling polymerization shrinkage stress.

CLINICAL SIGNIFICANCE

The clinical technique described in this article has the potential for being used routinely in treating noncarious cervical lesions, especially in cases without easy access and limited field control. Precise margin finishing and polishing is one of the greatest benefits of the class V direct-indirect approach, as the author has seen it work successfully in his practice over the past five years.

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INTRODUCTION

Noncarious cervical lesions (NCCLs) have long been a topic of concern for patients and clinicians due to their high prevalence and associated undesirable clinical problems, including esthetic compromise and dentinal sensitivity.[1–3] Etiologic factors described in the literature primarily include abrasion, acid erosion, and abfraction.

Abrasion is mechanical wear of hard tissues, and is most commonly associated with tooth brushing and abrasive dentifrices, but other factors might be involved in the process.[4] Erosion is nonbacterial acidic dissolution of the crystalline substances hydroxyapatite and fluorapatite present in both enamel and dentin.[5] Although the term “erosion” is extensively mentioned in the dental literature, a recent paper suggested that “biocorrosion” replace “erosion” because it more adequately explains tooth substance degradation caused by chemical, biochemical, and electrochemical degradation from exogenous and endogenous acids, proteolytic agents, and piezoelectric effects.[6]

Abfraction NCCLs are described as resulting from biomechanical loading forces exerted on teeth and concentrating at the cementoenamel junction, eventually causing teeth to flex, undergo fatigue breakdown, and lose enamel and dentin, typically producing wedge-shaped lesions.[7]

Evidence indicates that cyclic fatigue and biocorrosion contribute to the formation of NCCLs.[8] Ultimately, NCCLs result from combined biocorrosive, stress, and

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attrition mechanisms that interact at varying degrees to produce lesions of variable magnitude. The appearance of these lesions varies according to location and etiology, ranging from shallow saucer-like depressions to broad disk-shaped lesions, or to wedge-shaped lesions. The defect floor may be flat, indented, or sharply angled.[9]

Although high by anecdotal observation, NCCL prevalence is not well documented. Different authors have reported widely diverse results due to varying methodologies.[10–12] Despite the published disparity, the clinical presence of such lesions is real and affects all dental practices worldwide. In one significant study, 1,002 individuals and a total of 18,555 permanent teeth were examined to determine the prevalence and severity of NCCLs.[13] The results indicated that the lesions were caused by a combination of erosion, abrasion, and abfraction mechanisms. One in six teeth presented NCCLs. One in three premolars had a NCCL, with the lower premolars exhibiting more severe lesions. Buccal lesions were most frequent. Prevalence and severity of the lesions increased with age.

Another study examined 391 individuals and reported a frequency of wedge-shaped defects of 19.1% in the younger and 47.2% in the older populations studied.[10] The mean prevalence was three NCCLs per person. Hypersensitivity frequently accompanied the lesions.

The extensive numbers reported in both studies and the nature of the findings reinforce the importance of the clinician's understanding of the etiology of these lesions and the necessity for being equipped with clinical measures to diagnose, prevent, and intervene when indicated.

RESTORING NCCLs

Deciding whether or not to restore or perform grafting procedures as treatment for NCCLs remains subjective and controversial among clinicians, with lesion depth, lesion sensitivity, and professionals' desire to restore them the main criteria.[14] However, based on biomechanical principles, there are strong indications that NCCLs should be restored to counteract the degradation resulting from stress corrosion.[15] An indication for surgical root coverage arises when recession generates esthetic compromise, results in root sensitivity, or complicates home care procedures.[16,17]

Several effective techniques are currently available for providing root coverage and keratinized tissue gain for single or multiple cervical lesions with excellent prognosis.[18–20] The surgical approach should be the primary treatment alternative when gingival recession is associated with minor or no tooth cavitation and unaesthetic anatomical compromise (Figure 1A–D).

Cervical lesions that are 2 mm deep or shallower have a better prognosis. The clinical situations can be divided into the following: (1) root exposure with no cavitation, (2) root exposure with cavitation, and (3) no root exposure with cavitation. When cavitation

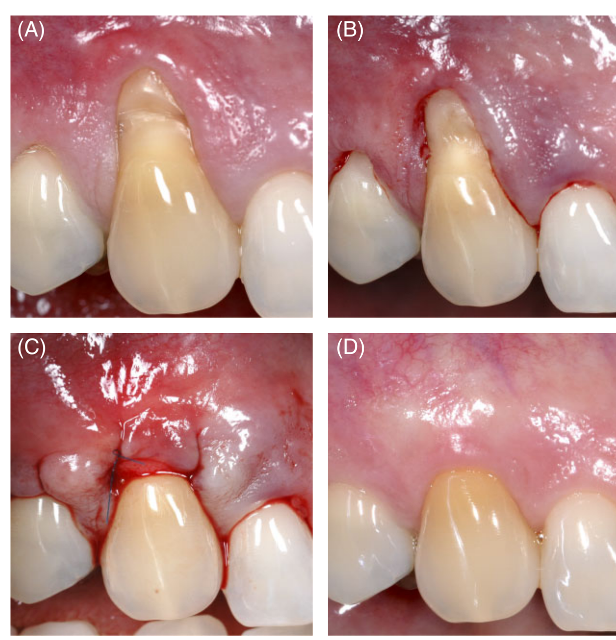

FIGURE 1. The surgical approach is the primary treatment alternative when gingival recession is associated with minor or no cavitation of the root surface and unaesthetic anatomical compromise. At 6-year follow-up, the grafting procedure shows excellent results with no relapse.

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involves the clinical crown with minor to no root exposure, adhesive restorative techniques are recommended.

CHOICE OF RESTORATIVE MATERIALS FOR NCCLs

Although silver amalgam and gold have been used for restoring cervical lesions for many decades and each demonstrates particular advantages and disadvantages, neither material is normally an appropriate option due to the more invasive nature of the cavity preparations, requiring retention form that is unnecessary with adhesive restorations. Furthermore, many patients no longer accept metal-based materials and expect tooth-colored restorations to be offered as treatment options in contemporary dental practices.

Because of their biocompatibility, adhesion, and fluoride release,[21] resin-modified glass ionomers (RMGI) are suggested as viable alternatives for restoring NCCLs, especially in caries-susceptible patients. Their clinical behavior, however, falls short compared with their composite resin counterparts regarding color stability, anatomical form, surface texture, marginal integrity, and marginal discoloration.[22,23] Related tooth-colored restoratives, such as polyacid-modified resin composites ("compomers"), are also available, but their clinical performance remains questionable compared with composite resins.[24,25] Sandwich techniques with either conventional or RMGI have also been advocated in attempts to combine the benefits of glass ionomer liners with veneering composite resin layers.[26,27] Although the technique may have some benefits (e.g., improved marginal seal), its advantages over composite resins alone are questionable.[28]

COMPOSITE RESINS: CHALLENGES AND DIFFICULTIES WHEN RESTORING NCCLs

In addition to their excellent physical and optical properties, composites can easily be manipulated, inserted, sculpted, and light-activated, making them the material of choice for restoring class V defects. The direct approach has been the primary method for restoring both carious and NCCLs.[29] However, as simple as the direct approach may be, there are challenges and difficulties associated with this conventional restorative technique.

Among these is access to difficult-to-reach areas, as in NCCLs on first or second maxillary molars (Figure 2). The ramus and cheeks frequently defy careful and precise instrumentation of the lesions and make material placement and contouring quite difficult. The second issue involves field control, which can be conventionally achieved using a rubber dam and clamps to retract the gingival margins. Clamp placement frequently aggravates the soft tissue, especially in lesions with deep subgingival margins that require the use of anesthetic to avert sensitivity and discomfort (Figure 3A–D). However, the mere sting of a needle itself aggravates most patients. An alternative field control method is the modified isolation technique, which requires packing retraction cords to block intra-crevicular fluid and provide access to cavity

FIGURE 2. Difficult-to-reach areas, such as NCCLs on first and second maxillary molars, present an operative challenge because the ramus and cheeks make instrumentation of the lesions, material placement, and contouring difficult. Red arrows indicate the most difficult access areas.

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FIGURE 3. Clamp placement frequently aggravates the soft tissue, especially in lesions with deep subgingival margins, which requires the use of anesthetic to prevent sensitivity and discomfort.

margins. Although this alternative procedure can often be accomplished without anesthesia, the issue of contamination remains, especially in the mandibular arch. Furthermore, the use of rotary instruments present additional subgingival marginal finishing and polishing challenges, such as invariably scarring soft tissue, leading to potential discomfort and gingival recession. Finally, if addressed with the conventional direct method, restoring multiple lesions in a quadrant during a single appointment requires a long appointment time, which can generate some patient distress. Treating several teeth at once requires each lesion to be restored individually, following the protocol steps one by one to avoid contaminating the adhesive interface and optimize material placement and finishing.

THE DIRECT-INDIRECT TECHNIQUE

A direct-indirect technique is one in which the composite resin is directly applied and sculpted onto the tooth surface prior to acid-etching and adhesive application. It is then light-activated, removed, and finished extraorally prior to indirect adhesive cementation. Also called *semi-direct*, this technique has anterior and posterior applications, and its advantages have been considerably discussed in the literature.[30–33] When initially introduced, the technique's greatest benefits emphasized the ability to subject the chairside-fabricated veneers (Figure 4A–D) or inlays to additional light-curing and heat-tempering processing, which enhanced the physical properties and clinical behavior of the finished composite restorations due to increased monomer conversion.[34–37] Benefits beyond improved physical properties, however, render the direct-indirect technique an optimal restorative choice and paramount in providing enhanced clinical results because it facilitates greater operator control over the final anatomical and color outcome. Especially in the case of direct-indirect composite resin veneers, the advantages far surpass those of the direct veneer (Table 1).[32]

THE DIRECT-INDIRECT CLASS V RESTORATION

The direct-indirect class V restoration naturally evolved from its direct-indirect veneer counterpart, as it is actually a semi-veneer covering the cervical and possibly the middle third of the clinical crown, depending on the size of the lesion. Like the veneer technique, the composite resin is applied and sculpted onto the cervical lesion, light-activated, removed, finished, polished, and bonded. Because some NCCLs are deep and V-shaped, and considering that these restorations are cemented, direct-indirect class Vs might alternatively be termed *class V composite inlays*.

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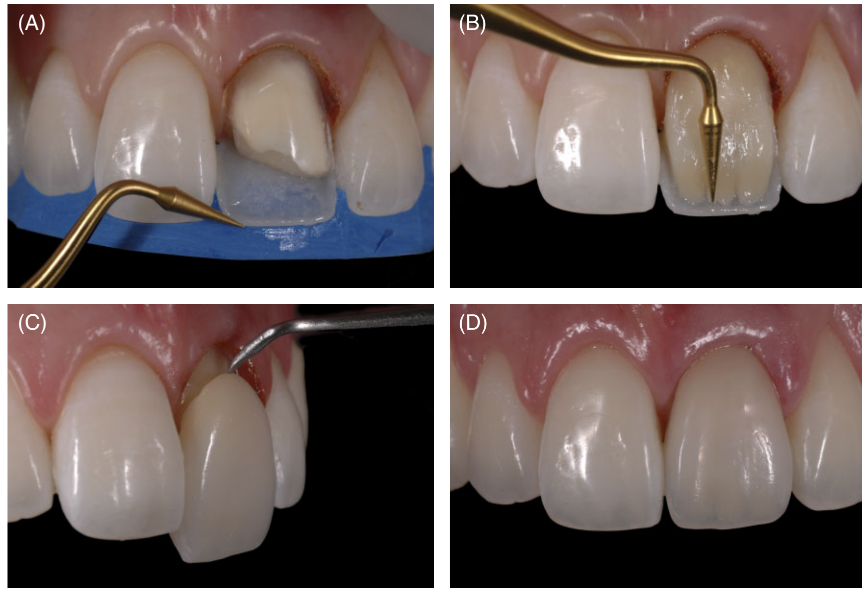

FIGURE 4. Direct-indirect veneers offer the added benefits of chairside fabrication and cementation associated with improved physical properties as well as optimal color and form integration.

TABLE 1. Comparison between direct and direct-indirect composite resin veneers

Capabilities	Direct	Direct-indirect
Accomplished in one appointment	✓	✓
Chance for corrections	—	✓
Shade try-in	—	✓
Enhanced physical properties	—	✓
Marginal polish	—	✓
Marginal adaptation	—	✓
Periodontal health maintenance	—	✓

When compared with the direct technique, the direct-indirect class V restoration provides several advantages (Table 2).

Access to Difficult-to-Reach Areas

Canines and premolars are usually easy to reach operatively and present no major challenge to the direct approach. Molars, in contrast, introduce greater difficulty to even a skilled operator because of inaccessibility due to tooth position in relation to soft and hard tissues. Direct instrumentation in those areas (e.g., cavity preparation, material placement, contouring) is cumbersome and elusive at times. The direct-indirect approach effectively circumvents these problems because the composite is applied in larger increments and pressed over the lesion and beyond the gingival margin without much need for precise contouring. The operator initially uses a finger and contouring instruments to achieve a gross anatomical shape, which will subsequently be precisely refined extraorally after light-activation and restoration removal from the cavity.

Field Control

The orthodox direct approach for restoring class Vs mandates absolute field control (i.e., rubber dam). The benefits of this technique are obvious, as it provides the operator prolonged working time without worrying about contamination, especially in the lower arch and situations of poor periodontal health. Alternatively, modified rubber dam techniques and retraction cords can be indicated for periodontally healthy patients and where margins are not too subgingival.

With the direct-indirect class V technique, alternative field control measures are indicated, precluding the use of conventional rubber damming and clamps. The class V inlays are adhesively cemented, therefore, allowing reduced exposure of the bonding agent to oral cavity moisture and further contamination. The level of field

TABLE 2. Comparison between direct and direct-indirect class V restorations

Attributes	Direct	Direct-indirect
Access to difficult-to-reach areas	Difficult	Easy
Field control	Rubber dam or modified isolation	Modified isolation
Composite handling	Totally intraoral	Intra- and extraoral
Stress caused by polymerization shrinkage on tooth	High	Low
Gingival margin finishing	Totally intraoral Accomplished with burs, discs, and rubber rotaries	Totally extraoral Completed with discs
Restoration marginal adaptation	Difficult to achieve	Excellent
Periodontal health maintenance	Dependent upon quality of gingival margins	Excellent
Patient comfort	Low	High

control varies by case and influences whether multiple inlays can be luted one-by-one or all at once.

Composite Handling

Composite resin handling can vary from very easy to extremely difficult, depending on lesion location and effectiveness of the selected field control technique. In easily accessible areas, the operator has prolonged working time, and the composite application, modeling, curing, finishing, and polishing becomes stress-free. When hard-to-reach areas are restored, the direct-indirect technique presents one of its greatest benefits, which is relieving the operator concern about precise intraoral contouring and enabling completion of almost all finishing and polishing extraorally. However, handling a composite inlay of minute dimension during finishing and polishing may be a major challenge until the operator reaches his or her comfort zone.

Stress Caused by Polymerization Shrinkage on Tooth

The composite resin quantity, cavity geometry, and C-factor are reported to influence the shrinkage stress exerted on the tooth in class V restorations.[38,39] Layering techniques have been advocated to minimize the undesired consequences of composite shrinkage (i.e., post-operative sensitivity, microleakage),[40–42] but there are divergent findings regarding the efficacy of incremental layering versus bulk filling.[43–45] The benefits of bulk filling class V defects, however, make it more attractive to operators, because they frequently include use of a single shade, thus minimizing the number of steps and reducing operative time. Depending on cavity/lesion size and depth, incremental layering or bulk filling may be indicated for both the direct and direct-indirect class V approaches, primarily for esthetic reasons, as composites of varying chroma and opacity may be utilized. Because the direct-indirect technique advocates supplemental secondary light-activation of the class V inlay extraorally, the bulk fill technique should be used whenever possible. The additional extraoral light cure counteracts problems associated with insufficient curing at the bottom of thicker inlays.

Gingival Margin Finishing

Marginal finishing for the direct-indirect class V restorations resembles the process for finishing relined provisional margins. Once the composite is pressed over the cervical margin of the lesion and extended over the free gingival margin, it is light-cured and removed from the mouth. The margins are outlined with a pencil for precise visualization, and finishing is completed with discs. Magnification (e.g., loupes or microscope), in combination with the sequential use of

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discs of varying grits, permits finishing the margins to the utmost contour and polish. Unlike the direct-indirect method, finishing direct class V cervical margins intraorally can be difficult and demonstrate less than ideal outcomes, especially in subgingival margins in hard-to-reach areas. Potential problems arising from direct finishing include, but are not limited to, flash and overhangs, rough gingival margins, and nicking the cementum as a result of poor access to and instrumentation of the margins.

Restoration Marginal Adaptation

Adaptation of the composite to the cervical margin of a NCCL using the conventional technique involves contouring instruments and brushes. Marginal sealing and tightness of the tooth-composite interface depends upon proper material placement and implementation of proper adhesive protocols.[46] In straightforward clinical scenarios, achieving a tight marginal seal can be fairly predictable with satisfactory results. Once again, it is in difficult cases that adaptation problems are likely to arise. In an in vitro study, Haller and colleagues investigated the marginal seal of cervical composite inlays in comparison to conventional class V restorations.[47] The results showed better performance of the inlays regarding microleakage. In the study, the inlays were further subjected to additional light-curing and heat tempering, which made the bonded inlays more resistant to thermal stress, probably by relaxing material stress and enhancing bond stability. The direct-indirect class V restoration achieves the same benefits of stress reduction through the material application and polymerization mechanisms employed, providing a much better marginal adaptation.

Periodontal Health

The effects of subgingival restorations on periodontal health have been widely investigated. Problems associated with restorative material type and poorly finished restorations include a change in the subgingival microflora leading to plaque accumulation, gingivitis, and recurrent caries.[48–51] Because achieving excellent margins through utmost surface and marginal polish becomes imperative, so does selecting proper finishing and polishing techniques. Several papers confirm that the smoothest composite resin surface can be achieved by using aluminum oxide finishing discs.[52] It is impossible to intraorally gain access to subgingival margins with discs unless some means of gingival retraction is utilized. This leaves the only option of using burs and rubber polishers for smoothing margins, and a perfect result is seldom achieved. However, extraoral finishing and polishing of class V inlays provide unmatched surface smoothness, which, in turn, promotes less plaque retention and, consequently, a healthier periodontal environment.

Patient Comfort

The direct-indirect class V technique provides a more comfortable experience for the patient versus the direct technique. There is minimal intraoral working time, which reduces the length of time patients keep their mouths open, allowing them to rest between restorative steps. Anesthesia is seldom needed, even when packing retraction cords is required. Perhaps the greatest comfort provided by the inlay technique results from the absence of subgingival finishing. Other than removing minor flash of luting resin at the gel stage with a sickle scaler or similar instrument and buffing the restoration surface with rubber cups, there is no aggressive contact with the soft tissue. As stated previously, scarring of gingival tissue and nicking the cementum/root surface during operative procedures is a nuisance and cause of great uneasiness to patients. This benefit becomes evident immediately after completing treatment, when no damage to either tooth or periodontium ensues, and sound integration between soft tissue and restoration is perceived (Figure 5A–D).

THE TECHNIQUE

Step 1. Composite Selection

Physical Properties

In terms of physical properties, the criteria for selecting restorative composite resins include modulus of elasticity, handling, resistance to wear, and

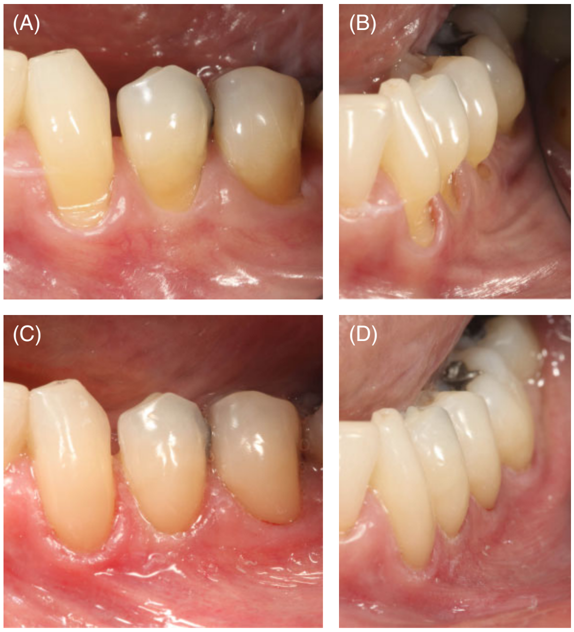

FIGURE 5. Sound integration between soft tissue and restoration are noteworthy immediately after completion of four direct-indirect Class V inlays in a single appointment, with virtually no discomfort to the patient.

polishability. Controversy exists regarding the extent to which compressive versus tensile stresses plays a role in retentive failure in vivo of stress-induced NCCLs, and the choice of a lower over a higher modulus of elasticity composite to enable better stress distribution remains debatable.[53–55] Predicting failure risk of the tooth-restoration adhesive interface based on stress dissipation properties alone is difficult both in vitro and in vivo due to the essentially deformable nature of composites and the interrelationship between the actual composite resin, tooth substrate, and periodontal ligament.[56] While the use of microfills has been recommended for stress-generated NCCLs based on their higher resiliency and lower modulus of elasticity, controversy surrounds this recommendation.[57]

Although most state-of-the-art composites could be indicated for restoring NCCLs, the author prefers to use microfill or nanofill restoratives because of the excellent inherent properties related to their filler size and distribution. Their handling and polishability enable proper manipulation and sculptability, and promote excellent surface smoothness and gloss.[58–60] Surface smoothness of composite resins has been shown to directly correlate with gloss.[61] Change in gloss is primarily influenced by composite resin material characteristics (i.e., filler type, distribution, resin matrix chemistry).[62]

Of equal clinical relevance, wear is another important characteristic when selecting the composite resin for a NCCL class V restoration that will be subjected to intraoral abrasion from whichever source. Despite its importance, however, reported wear rates should not dictate restorative composite resin selection for a NCCL, since clinical assessment of wear is not as easily accomplished as in a laboratory setting, given the many variables involved in producing wear. While conventional and reinforced microfills (e.g., Renamel Microfill, Cosmedent, Chicago, IL; Micronew, Bisco, Inc., Schaumburg, IL) provide excellent polish and gloss, wear rates vary according to product brand and composition. This fact per se should not preclude the clinical use of microfills, as they have demonstrated superior clinical performance. Submicron-filled composites have been reported to exhibit both high gloss and have low wear rates,[62] which provides a strong indication for their clinical implementation in NCCLs. A few commercial products include Estelite Omega and Estelite Asteria (Tokuyama Dental, Taitou-kuTokyo, Japan), and Filtek Supreme Ultra (3M ESPE, St. Paul, MN, USA).

Shade and Optical Properties

In cases of no root exposure with cavitation and minor root exposure with cavitation, tooth-colored composites are indicated. The cervical one-third of the natural dentition presents higher opacity and accentuated chroma because the dentin is at its thickest and the enamel is at its thinnest, making the inner dentin color show through the thin outer enamel. Optically, this demands the use of composite resins that replicate natural dentin and enamel to achieve a seamless restoration.

This can be achieved either by (1) using artificial dentin and enamel composites as separate layers, or (2) utilizing a single layer of a composite shade of an

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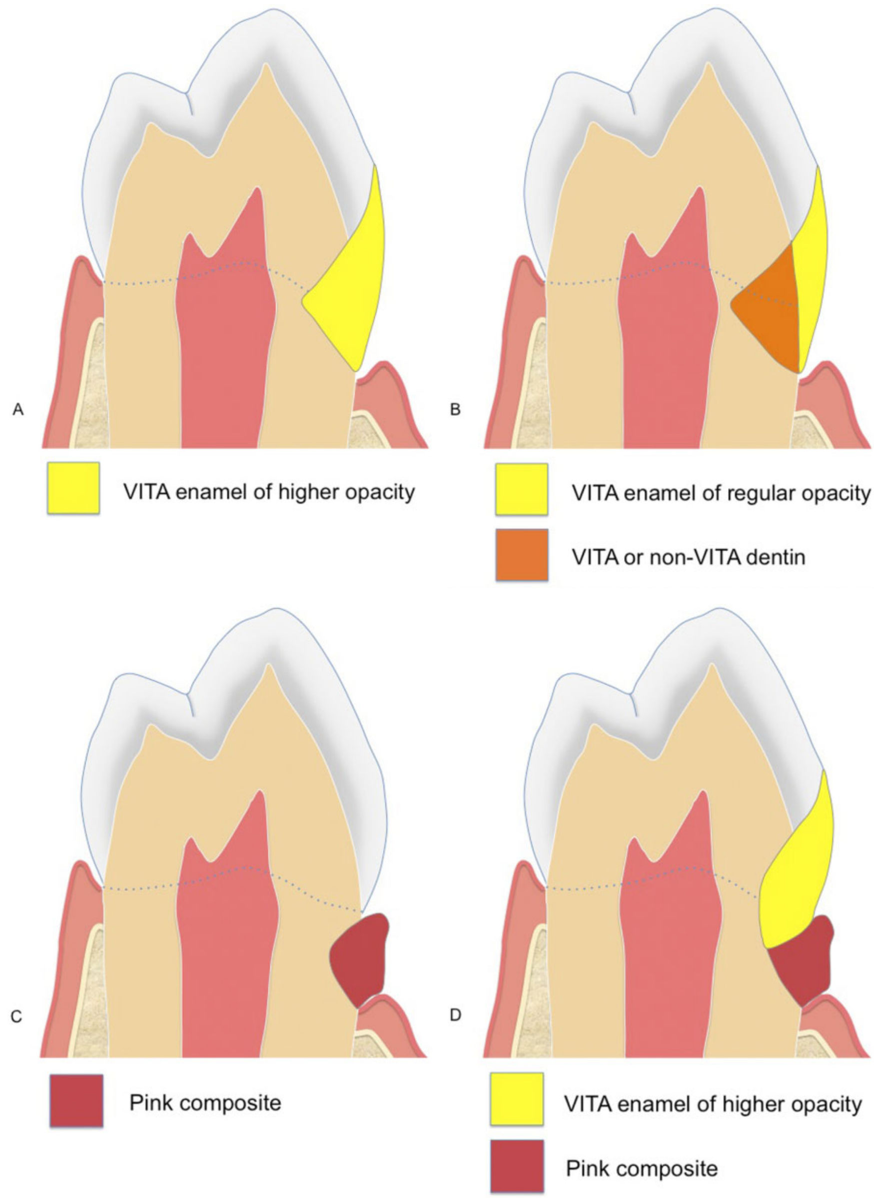

FIGURE 6. A: VITA-based enamel composites of higher opacity and higher chroma blend well in deeper lesions, whereas in shallower lesions, more translucent VITA-enamels are indicated. B: In lesions deeper than 2.5 mm, a dentin composite may be used to provide the chroma base that can be veneered with either a VITA or non-VITA enamel composite. C: Pink composite is indicated for short and shallow root lesions that extend up to the DEJ without compromise of the natural enamel. D: In longer and deeper lesions affecting the coronal natural enamel and the root, a combination of VITA-based enamel and pink composite is used to re-establish pink and white esthetics.

intermediate opacity between the two. The first technique calls for selecting a higher chroma dentin shade than that intended. The veneering enamel composite can be selected according to either an (1) *polychromatic*[63] or (2) *natural layering*[64] approach. The *polychromatic* method uses a VITA-based[65] veneering enamel composite of the intended hue and chroma, and a dentin of the same hue but with a higher chroma. The *natural layering* method employs a VITA or non-VITA dentin composite of the desired hue with a higher than intended final chroma, and non-VITA enamel shade that modulates the dentin color to the desired chroma and value, while maintaining the same hue of the underlying dentin composite. Both techniques are equally effective, and the decision to utilize one over the other depends upon the operator's preference and mastery of the selected technique. The author favors the use of VITA enamel shades over non-VITA shades because they provide more predictability in attaining the final hue, chroma, and value of the cervical tooth color. Cavities deeper than 2.5 mm may be restored with the dual layer (i.e., dentin and enamel) approach. However, in most cases, a higher opacity VITA enamel suffices to provide the proper opacity/value while

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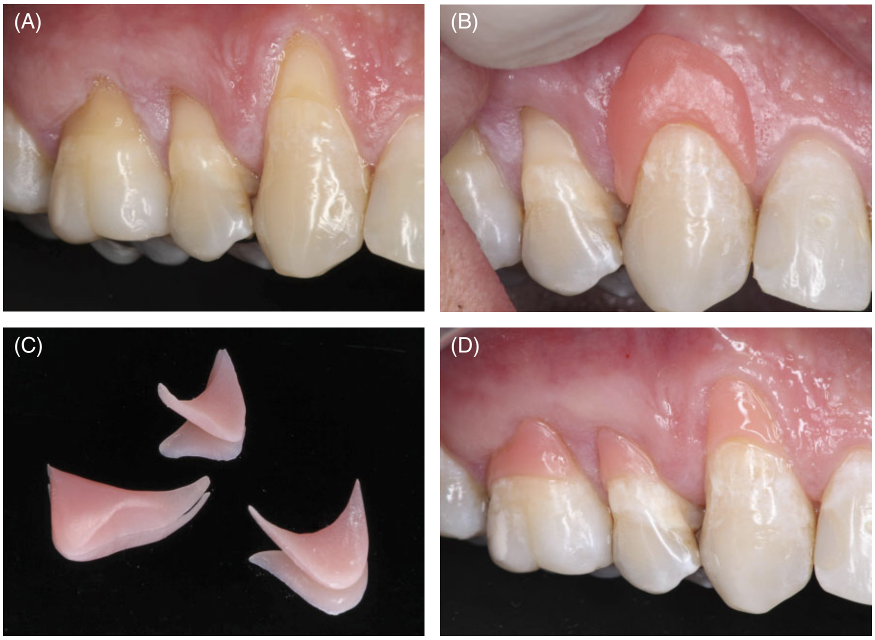

FIGURE 7. Gingiva-colored direct-indirect Class V restorations are indicated to minimize the long clinical crown appearance that would result if only tooth-colored composite were used.

imparting a natural depth and blending effect with the surrounding tooth structure and adjacent dentition (Figure 6A and B).

In cases where there is root exposure with no cavitation and grafting procedures are dismissed as a primary option, gingival-colored composites (e.g., Gingafill, Cosmedent, Chicago, IL; Amaris Gingiva, Vocco, Indian Land, SC) may be utilized alone (Figure 6C) or in combination with tooth-colored composites (Figure 6D). This approach minimizes the long-clinical-crown appearance that ensues if only tooth-colored composites are used, which invariably creates an unaesthetic result, especially when the restorations are displayed during the smile (Figures 7A–D and 8A–D).

Step 2. Cavity Preparation

Cavity preparation varies from none, in cases of erosion/abrasion lesions, to beveling of the enamel where wedge-shaped lesions with sharp enamel occlusal cavosurface margins present. In the former case, class V restorations may appear more like a thin contact lens veneer that may extend onto the middle and occlusal thirds, and in the latter, it assumes the actual shape of a class V inlay.

Step 3. Composite Application

If the cervical margin is equigingival or slightly subgingival, packing retraction cords is unnecessary. Packing a non-impregnated cord of adequate thickness may reveal margins that are deeper subgingivally and, thus, assist in imprinting the margins on the composite. For the more common scenario of lesions shallower than 2.5 mm, the selected single composite shade is made into a small ball that is rolled between the fingers and pressed onto the cervical lesion, covering not only the cavity, but also extending beyond its boundaries over the beveled enamel, interproximally and, most importantly, over the gingival margin (Figure 9A–C). Gentle finger pressure assures an accurate imprint of the gingival margin into the squashed composite increment. Although instruments may be used for further contour refinement, this is often not necessary, since all gross excess will be removed through extraoral finishing and polishing.

Step 4. Light-Activation and Restoration Removal

The restoration is thoroughly light-cured by providing proper light intensity and cure time, according to the type of curing unit employed (e.g., halogen, LED, plasma ARC). Using a curette, the restoration is flicked off and

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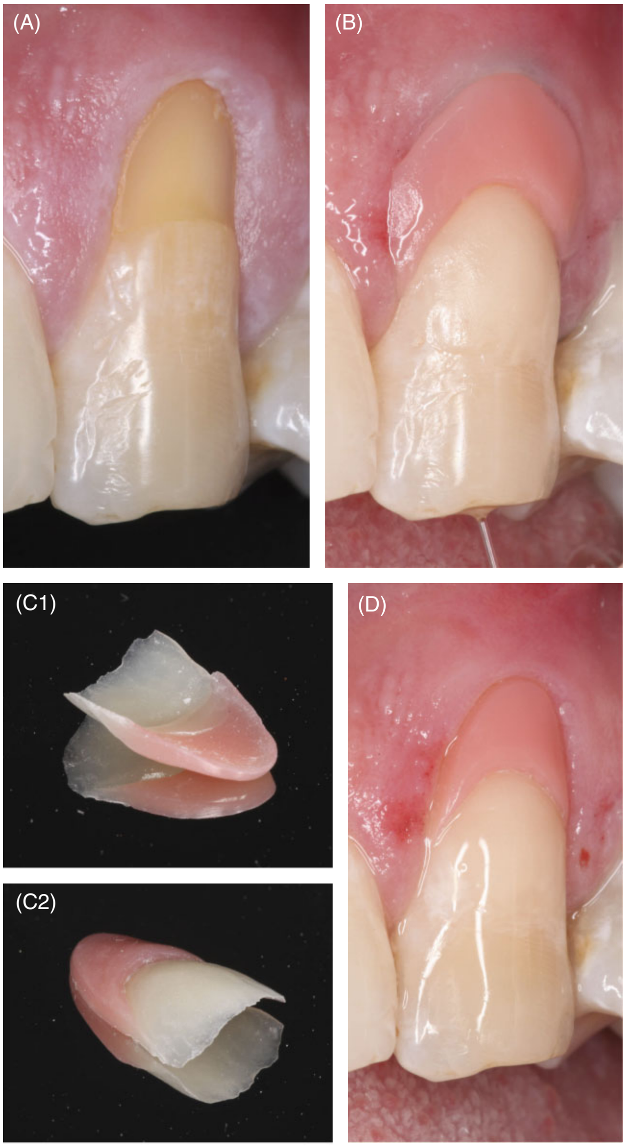

FIGURE 8. Tooth-colored and gingiva-colored composites are combined to reestablish proper morphology and color in cases of cavitated clinical crown and long gingival recession with root exposure.

further light-cured extraorally from its outer and inner aspects to ensure adequate polymerization.

A thick direct class V restored using the bulk fill technique would normally require an extended light exposure for maximum polymerization, and this prolonged curing time may have deleterious effects on the pulp.[66,67] Performing the final light-cure extraorally for the direct-indirect class V restoration allows for prolonged light exposure as needed without concern for potential pulp damage arising from increased temperature.

Step 5. Extraoral Finishing and Polishing

The imprinted cervical margin is clearly evident on the cured composite, and a pencil is used to outline its fine edges, facilitating visualization during the finishing stage. Aluminum oxide discs of varying grits are used sequentially to remove the gross excess, and to finish and polish the margins to ideal contour, smoothness, and gloss (Figure 10).

Step 6. Surface Pre-Cementation Treatment of Restoration

The restoration inner surface is airborne particle-abraded using 27–50 μm aluminum oxide particles, or alternatively with a 30 μm silicate ceramic (e.g., CoJet, 3M ESPE, St. Paul, MN) (Figure 11). Although composite resins vary considerably and may require different protocols for adhesive cementation, mechanical roughening is reported to produce effective bond strengths on microfills, hybrids, and nanofills.[68,69] After air abrasion, the intaglio of the restoration is cleaned with 35–40% phosphoric acid for 10 seconds, rinsed, and dried. Silanation has been shown to enhance bond strengths of laboratory processed composites[70] and may be incorporated as an additional step for the direct-indirect class V technique. Despite the proven benefits of silane application, this step is optional, as its advantages in class V inlays have not yet been reported. Next, a hydrophobic adhesive resin (e.g., All Bond 3, Bisco, Inc., Schaumburg, IL; OptiBond FL, Kerr Corporation, Orange, CA, USA; Scotchbond MP, 3M ESPE, St. Paul, MN, USA) is applied and air-thinned. The inlay is set aside under a light-protective shield until cementation. If more than one inlay is being completed, the clinician should be organized in the sequence according to which they will be cemented.

Step 7. Surface Pre-Cementation Treatment of NCCLs

Following the packing of the retraction cord to reveal the dentinal margin, the dentin and enamel surfaces of the cavity are airborne particle-abraded with 27–50 μm aluminum oxide (Figure 12A and B). This step enhances bond strengths by roughening the dentin and removing

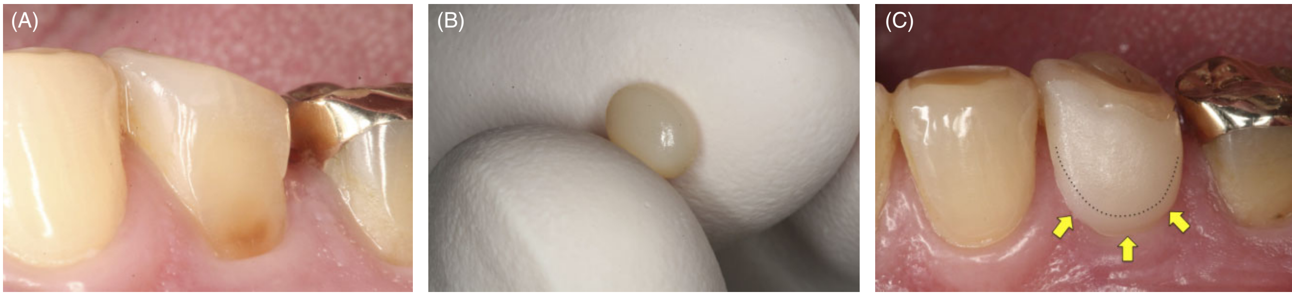

FIGURE 9. A single composite shade is made into a small ball and then pressed onto the cervical lesion, covering the free gingival margin.

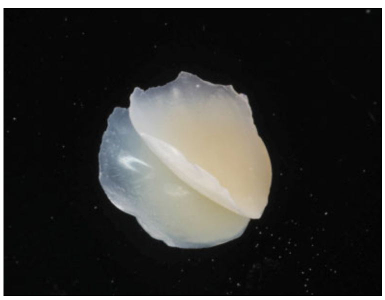

FIGURE 10. After light-curing, the inlay is flaked off and aluminum oxide discs of varying grits are used sequentially to finish and polish the margins to ideal contour, smoothness, and gloss.

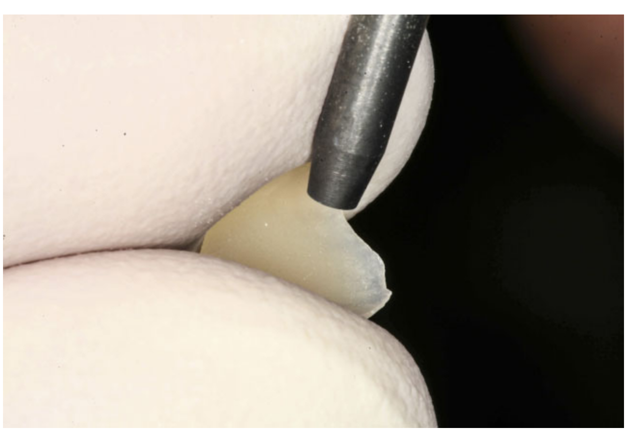

FIGURE 11. The intaglio surface is airborne particle-abraded with 27–50 µm aluminum oxide particles, or with a 30-µm silicate ceramic to enhance bond strength.

the aprismatic layer of uninstrumented enamel beyond the bevel line, thus enhancing bonding in that area.[71,72] Air abrasion of enamel and dentin promotes similar bond strengths for both etch-and-rinse and self-etch adhesives, although the tag formation seems to be more

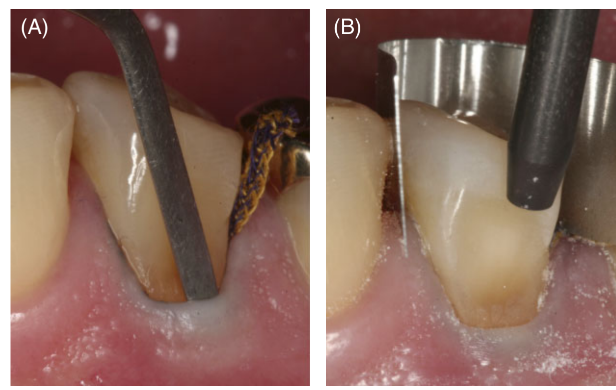

FIGURE 12. Retraction cord is packed to reveal the dentinal margin and the cavity is abraded with 27–50-µm aluminum oxide.

evident for self-etch adhesives.[72] A recently published literature review concerning the effectiveness of self-etch versus etch-and-rinse adhesives with multiple steps for treating NCCLs determined that there is insufficient evidence to support one adhesive or bonding protocol over another.[73] Clinical judgment at the time of the procedure should determine adhesive selection. For example, if gingival inflammation is present, using a three-step total-etch adhesive that requires acid-etching may be contraindicated, because the acid will likely promote bleeding. This is not the case with self-etch adhesives that tend to be gentler on the soft tissue and do not provoke bleeding upon contact with the gingiva, even if moderately inflamed. Three-step total-etch adhesives are considered the gold standard and, therefore, may be considered a primary choice over other adhesives.[74]

The dentin and enamel are etched with 35–40% phosphoric acid for 15 seconds and rinsed. Surface

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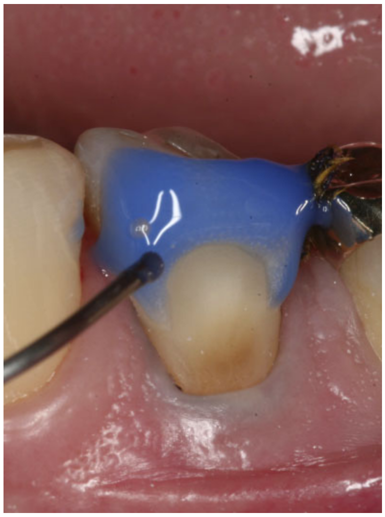

FIGURE 13. Dentin and enamel are etched with 35–40% phosphoric acid for 15 seconds to comply with a three-step etch-and-rinse adhesive application protocol.

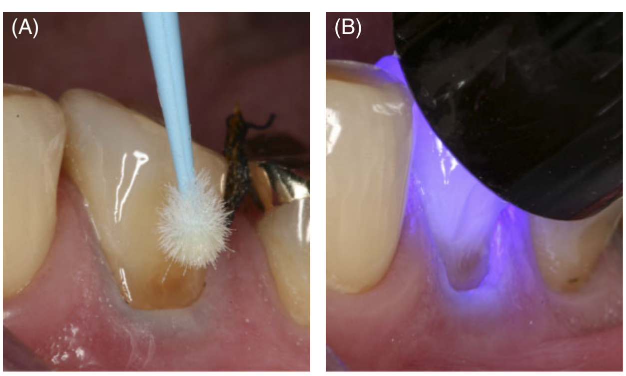

FIGURE 14. Following primer application, a thin coat of hydrophobic adhesive is applied, and light-cured.

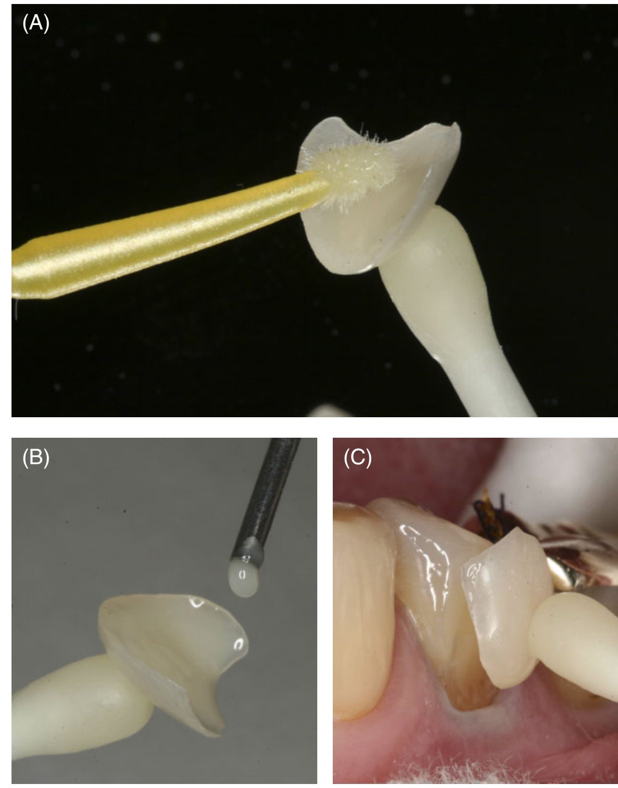

FIGURE 15. The inlay is covered with a thin coat of hydrophobic adhesive, followed by luting resin, and it is carried onto the pre-hybridized lesion.

moisture control is completed by aspirating excess water (Figure 13). Filled three-step total-etch adhesives are preferable for this technique based on the benefits they present.[75] A primer is applied (e.g., All Bond 3 A&B, Bisco, Inc., Schaumburg, IL; OptiBond FL, Kerr Corporation, Orange, CA) and agitated onto the dentin surface for at least 20 seconds. Excess primer is aspirated, and the remnant solvent is further volatilized by gentle air spray. A thin coat of hydrophobic adhesive is applied, excess is aspirated, and the adhesive light-activated (Figure 14A and B). The filler content of the adhesive creates a slightly thicker layer that enhances bond strength and minimizes microleakage, promoting longer life expectancy in the class V restoration.[76,77] Although the adhesive is cured prior to cementation, the composite inlay will fit properly, since sandblasting provides room to accommodate adhesive thickness.

Step 8. Cementation of the Class V Inlay

A light-cured resin luting cement or flowable restorative composite resin can be used for cementing the class V inlay. Translucent resin of any shade usually provides good color blending and elicits natural looking results. A thin coat of hydrophobic adhesive is applied to the intaglio of the inlay, which is subsequently covered with the selected luting resin, and carried onto the pre-hybridized lesion with tweezers or a sticky handle (Figure 15A–C). Once positioned, the inlay is pressed to ooze the excess luting resin. A small-tipped light guide (e.g., VALO, Ultradent Products, Inc., South Jordan, UT; Optilux Demetron, Kerr Corporation,

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FIGURE 16. A small-tipped light guide is used to spot light-cure the Class V inlay for 1–3 seconds.

FIGURE 17. The luting resin, which has reached a gel stage, is removed with a sickle, and the interproximal areas are checked with dental floss to ensure complete removal of luting resin.

Orange, CA) is used to push the inlay into position away from the cervical margin, and it is spot-cured for 1–3 seconds, depending on the intensity of the curing unit (Figure 16). The luting resin, which has reached a gel stage, is removed with a sickle, and the interproximal areas are checked with dental floss to ensure complete removal of luting resin (Figure 17). An air-inhibiting gel is applied over the spot-cured inlay, and final light-curing is realized for the length of time necessary according to the curing unit used (Figure 18). The adhesive tooth-inlay interface depicts an enhanced

FIGURE 18. Final light-curing of the spot-cured inlay is realized for the length of time necessary according to the intensity of curing unit used.

micromechanical as well as physical-chemical link to ensure optimal bond of the restoration (Figure 19).

Step 9. Final Finishing and Polishing

The occlusal margin of the inlay will frequently demonstrate a thicker rim requiring additional intraoral refining. Finishing discs of varying grits are used sequentially to finesse any roughness and execute minor contour changes. As the gingival margins of the inlay have been previously finished and polished, touching these areas with rotary instruments should be avoided to prevent unnecessary scratching of the smooth and glossy surface. Next, rubber polishing points and cups are used, followed by felt discs and polishing pastes, to bring the class V inlay to its final surface polish and gloss (Figure 20A). Meticulous attention to material selection, cavity preparation, adhesive protocol, and light-curing, in addition to precise finishing and polishing techniques, assures a potentially long-lasting result for direct-indirect class V inlays (Figure 20B).

DISCUSSION

The direct-indirect class V composite inlay technique may seem cumbersome and difficult to implement clinically at first glance, since it advocates a completely different paradigm compared with conventional direct

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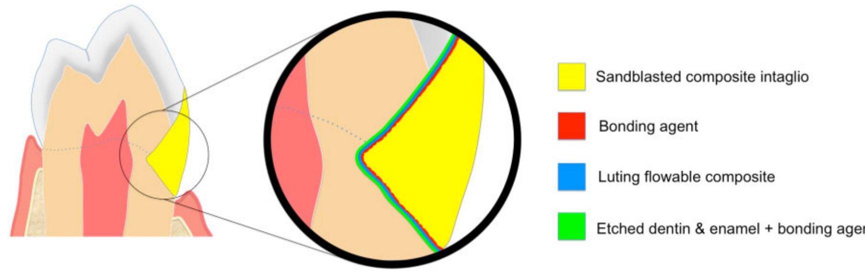

FIGURE 19. Optimal bond of the restoration is assured by micromechanical as well as physical-chemical links at the tooth-inlay interface.

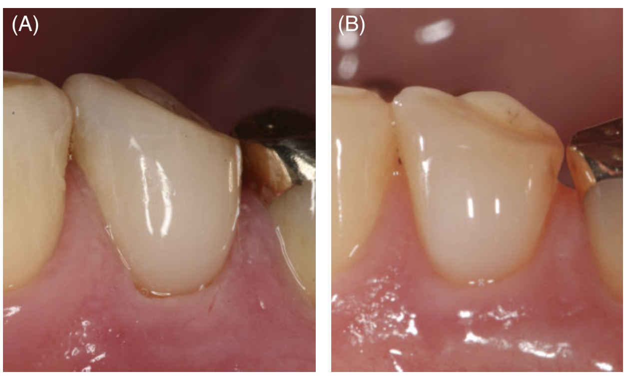

FIGURE 20. The immediate post-operative result shows a sound integration of form and color, and moreover excellent soft tissue response to the restorative process. At four years and seven months the restoration shows excellent color stability, anatomical integrity, and a healthy periodontal response.

class V restorations. Certainly, the direct approach is unquestionably a viable option and could still be considered the primary indication for carious or NCCLs with easy access and where field control does not pose a challenge. The change in mentality beginning to consider executing the direct-indirect technique requires a learning curve of working with tiny inlays intra- and extraorally. For that reason, using high magnification loupes or microscopes is essential if precise margin finishing and polishing is to be achieved, which is one of the greatest benefits of this novel approach. Frequently, the operator will require a change in gloves because of cuts or tears from the discs during finishing, due to the difficulty in handling such small restorations. Because of their minute size, preventing the inlays from flying from one's hands across the operatory room while handling them during finishing and polishing is also an expected challenge. Loss of some restorations is to be anticipated, and remakes are sometimes necessary.

The author has a 4.5-year follow-up involving 62 direct-indirect class V composite inlays, a few made from microfills and the vast majority from nanofills, all of which demonstrate immaculate polish and excellent marginal integrity. The adhesive protocols employed varied from case to case and included one-step and two-step self-etch adhesives with selective enamel etching and etch-and-rinse three-step adhesives. Of the 62 restorations, only one inlay debonded within four years and required remake. Future in vitro research should be conducted to ascertain the most appropriate bonding protocol for this technique, as well as to evaluate the quality of the marginal seal and integrity of the adhesive interface in comparison the conventional direct restorative approach.

CONCLUSION

The novel technique presented in this article optimizes the treatment of NCCLs through the creation of direct-indirect class V restorations. The greatest benefits of this technique are precise extra-oral margin finishing and polishing, and overcoming challenges associated with field control, composite handling, maintaining periodontal health, and controlling polymerization shrinkage stress.

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REFERENCES

1. Miller N, Penaud J, Ambrosini P, et al. Analysis of etiologic factors and periodontal conditions involved with 309 abfractions. J Clin Periodontol 2003;30(9):828–32.
2. Osborne-Smith KL, Burke FJ, Wilson NH. The aetiology of the non-carious cervical lesion. Int Dent J 1999;49(3):139–43.
3. Wood I, Jawad Z, Paisley C, Brunton P. Non-carious cervical tooth surface loss: a literature review. J Dent 2008;36(10):759–66.
4. Litonjua LA, Andreana S, Cohen RE. Toothbrush abrasions and noncarious cervical lesions: evolving concepts. Compend Contin Educ Dent 2005;26(11):767–8, 770–4, 776.
5. Bassiouny MA. Effects of common beverages on the development of cervical erosion lesions. Gen Dent 2009;57(3):212–23. quiz 224–5.
6. Grippo JO, Simring M, Coleman TA. Abfraction, abrasion, biocorrosion, and the enigma of noncarious cervical lesions: a 20-year perspective. J Esthet Restor Dent 2012;24(1):10–23.
7. Grippo JO. Abfractions: a new classification of hard tissue lesions of teeth. J Esthet Dent 1991;3(1):14–9.
8. Grippo JO, Chaiyabutr Y, Kois JC. Effects of cyclic fatigue stress-biocorrosion on noncarious cervical lesions. J Esthet Restor Dent 2013;25(4):265–72.
9. Levitch LC, Bader JD, Shugars DA, Heymann HO. Non-carious cervical lesions. J Dent 1994;22(4):195–207.
10. Lussi AR, Schaffner M, Hotz P, Suter P. Epidemiology and risk factors of wedge-shaped defects in a Swiss population. Schweiz Monatsschr Zahnmed 1993;103(3):276–80.
11. Al-Dlaigan YH, Shaw L, Smith A. Dental erosion in a group of British 14-year-old, school children. Part I: prevalence and influence of differing socioeconomic backgrounds. Br Dent J 2001;190(3):145–9.
12. Smith WA, Marchan S, Rafeek RN. The prevalence and severity of non-carious cervical lesions in a group of patients attending a university hospital in Trinidad. J Oral Rehabil 2008;35(2):128–34.
13. Borcic J, Anic I, Urek MM, Ferreri S. The prevalence of non-carious cervical lesions in permanent dentition. J Oral Rehabil 2004;31(2):117–23.
14. Estafan A, Bartlett D, Goldstein G. A survey of management strategies for noncarious cervical lesions. Int J Prosthodont 2014;27(1):87–90.
15. Grippo JO. Noncarious cervical lesions: the decision to ignore or restore. J Esthet Dent 1992;4(Suppl):55–64.
16. Tackas VJ. Root coverage techniques: a review. J West Soc Periodontol Periodontal Abstr 1995;43(1):5–14.
17. Weeks DB. Surgical coverage of exposed root surfaces: a review of available techniques and applications. Compend Contin Educ Dent 1993;14(9):1098–102, 1100. 1102 passim; quiz 1114.
18. Zucchelli G, De Sanctis M. Treatment of multiple recession-type defects in patients with esthetic demands. J Periodontol 2000;71(9):1506–14.
19. Zucchelli G, De Sanctis M. The coronally advanced flap for the treatment of multiple recession defects: a modified surgical approach for the upper anterior teeth. J Int Acad Periodontol 2007;9(3):96–103.
20. Bherwani C, Kulloli A, Kathariya R, et al. Zucchelli's technique or tunnel technique with subepithelial connective tissue graft for treatment of multiple gingival recessions. J Int Acad Periodontol 2014;16(2):34–42.
21. Kovarik RE, Haubenreich JE, Gore D. Glass ionomer cements: a review of composition, chemistry, and biocompatibility as a dental and medical implant material. J Long Term Eff Med Implants 2005;15(6):655–71.
22. Folwaczny M, Loher C, Mehl A, et al. Tooth-colored filling materials for the restoration of cervical lesions: a 24-month follow-up study. Oper Dent 2000;25(4):251–8.
23. Smales RJ, Ng KK. Longevity of a resin-modified glass ionomer cement and a polyacid-modified resin composite restoring non-carious cervical lesions in a general dental practice. Aust Dent J 2004;49(4):196–200.
24. Burgess JO, Gallo JR, Ripps AH, et al. Clinical evaluation of four Class 5 restorative materials: 3-year recall. Am J Dent 2004;17(3):147–50.
25. Folwaczny M, Loher C, Mehl A, et al. Class V lesions restored with four different tooth-colored materials—3-year results. Clin Oral Investig 2001;5(1):31–9.
26. Sidhu SK. A comparative analysis of techniques of restoring cervical lesions. Quintessence Int 1993;24(8):553–9.
27. Francisconi LF, Scaffa PM, de Barros VR, et al. Glass ionomer cements and their role in the restoration of non-carious cervical lesions. J Appl Oral Sci 2009;17(5):364–9.
28. Trushkowsky RD, Gwinnett AJ. Microleakage of Class V composite, resin sandwich, and resin-modified glass ionomers. Am J Dent 1996;9(3):96–9.
29. Heymann HO. Class III and Class V modified cavity preparations for composite resins. J Tenn Dent Assoc 1983;63(4):46–9.
30. Birnbaum NS. Direct oven-tempered hybrid composite-resin laminate veneers. Pract Periodontics Aesthet Dent 1992;4(5):23–31.

DOI 10.1111/jerd.12151

31. Birnbaum NS. Heat-tempered composite resin laminate veneers. Curr Opin Cosmet Dent 1994;52–7.
32. Fahl Júnior N. The direct/indirect composite resin veneers: a case report. Pract Periodontics Aesthet Dent 1996;8(7):627–38. quiz 640.
33. Diestchi D, Spreafico R. Adhesive metal-free restorations. Current concepts for the esthetic treatment of posterior teeth. Chicago (IL): Quintessence; 1997.
34. Ferracane JL, Condon JR. Post-cure heat treatments for composites: properties and fractography. Dent Mater 1992;8(5):290–5.
35. Covey DA, Tahaney SR, Davenport JM. Mechanical properties of heat-treated composite resin restorative materials. J Prosthet Dent 1992;68(3):458–61.
36. Wassell RW, McCabe JF, Walls AW. Wear rates of regular and tempered composites. J Dent 1997;25(1):49–52.
37. Ferracane JL, Mitchem JC, Condon JR, Todd R. Wear and marginal breakdown of composites with various degrees of cure. J Dent Res 1997;76(8):1508–16.
38. Alomari QD, Barrieshi-Nusair K, Ali M. Effect of C-factor and LED curing mode on microleakage of Class V resin composite restorations. Eur J Dent 2011;5(4):400–8.
39. Borges AL, Borges AB, Xavier TA, et al. Impact of quantity of resin, C-factor, and geometry on resin composite polymerization shrinkage stress in Class V restorations. Oper Dent 2014;39(2):144–51.
40. Linden JJ, Swift EJ Jr. Microleakage of two new dentin adhesives. Am J Dent 1994;7(1):31–4.
41. Aranha AC, Pimento LA. Effect of two different restorative techniques using resin based composites on microleakage. Am J Dent 2004;17(2):99–103.
42. Owens BM, Johnson WW. Effect of insertion technique and adhesive system on microleakage of Class V resin composite restorations. J Adhes Dent 2005;7(4):303–8.
43. Winkler MM, Katona TR, Paydar NH. Finite element stress analysis of three filling techniques for class V light-cured composite restorations. J Dent Res 1996;75(7):1477–83.
44. Sensi LG, Marson FC, Baratieri LN, Monteiro Junior S. Effect of placement techniques on the marginal adaptation of Class V composite restorations. J Contemp Dent Pract 2005;6(4):17–25.
45. da Silva MA, de Oliveira GJ, Tonholo J, et al. Effect of the insertion and polymerization technique in composite resin restorations: analysis of marginal gap by atomic force microscopy. Microsc Microanal 2010;16(6):779–84.
46. Yazici AR, Celik C, Ozgünaltay G. Microleakage of different resin composite types. Quintessence Int 2004;35(10):790–4.
47. Haller B, Klaiber B, Secknus A. Marginal seal of cervical composite inlays in vitro. Dtsch Zahnarztl Z 1990;45(5):296–9, (Article in German).
48. Paolantonio M, D'Ercole S, Perinetti G, et al. Clinical and microbiological effects of different restorative materials on the periodontal tissues adjacent to subgingival class V restorations. J Clin Periodontol 2004;31(3):200–7.
49. Quirynen M, Bollen CM. The influence of surface roughness and surface-free energy on supra- and subgingival plaque formation in man. A review of the literature. J Clin Periodontol 1995;22(1):1–14.
50. Carlén A, Nikdel K, Wennerberg A, et al. Surface characteristics and in vitro biofilm formation on glass ionomer and composite resin. Biomaterials 2001;22(5):481–7.
51. Silvério Flausino J, Ferreira Soares PB, Florindo Carvalho VF, et al. Biofilm formation on different materials for tooth restoration: analysis of surface characteristics. J Mater Sci 2014;49(19):6820–9.
52. Gedik R, Hürmüzlü F, Coşkun A, et al. Surface roughness of new microhybrid resin-based composites. J Am Dent Assoc 2005;136(8):1106–12.
53. Lee WC, Eakle WS. Stress-induced cervical lesions: review of advances in the past 10 years. J Prosthet Dent 1996;75(5):487–94.
54. Shubhashini N, Meena N, Shetty A, et al. Finite element analysis of stress concentration in Class V restorations of four groups of restorative materials in mandibular premolar. J Conserv Dent 2008;11(3):121–6.
55. Yaman SD, Sahin M, Aydin C. Finite element analysis of strength characteristics of various resin based restorative materials in Class V cavities. J Oral Rehabil 2003;30(6):630–41.
56. Wakabayashi N, Ona M, Suzuki T, Igarashi Y. Nonlinear finite element analyses: advances and challenges in dental applications. J Dent 2008;36(7):463–71.
57. Peumans M, De Munck J, Van Landuyt KL, et al. Restoring cervical lesions with flexible composites. Dent Mater 2007;23(6):749–54.
58. Da Costa JB, Goncalves F, Ferracane JL. Comparison of two-step versus four-step composite finishing/polishing disc systems: evaluation of a new two-step composite polishing disc system. Oper Dent 2011;36(2):205–12.
59. Da Costa J, Ferracane J, Paravina RD, et al. The effect of different polishing systems on surface roughness and gloss of various resin composites. J Esthet Restor Dent 2007;19(4):214–24. discussion 225–6.
60. Hosoya Y, Shiraishi T, Odatsu T, et al. Effects of polishing on surface roughness, gloss, and color of resin composites. J Oral Sci 2011;53(3):283–91.
61. Paravina RD, Roeder L, Lu H, et al. Effect of finishing and polishing procedures on surface roughness, gloss and

color of resin-based composites. Am J Dent 2004;17(4):262–6.
62. Lee YK, Lu H, Oguri M, Powers JM. Changes in gloss after simulated generalized wear of composite resins. J Prosthet Dent 2005;94(4):370–6.
63. Fahl N Jr, Denehy GE, Jackson RD. Protocol for predictable restoration of anterior teeth with composite resins. Pract Periodontics Aesthet Dent 1995;7(8):13–21. quiz 22.
64. Dietschi D, Ardu S, Krejci I. A new shading concept based on natural tooth color applied to direct composite restorations. Quintessence Int 2006;37(2):91–102.
65. Fahl N Jr. Mastering composite artistry to create anterior masterpieces—part 1. J Cosmet Dent 2010;26(3):56–68.
66. Zach L, Cohen G. Pulp response to externally applied heat. Oral Surg Oral Med Oral Pathol 1965;19:515–30.
67. Oberholzer TG, Makofane ME, du Preez IC, George R. Modern high powered led curing lights and their effect on pulp chamber temperature of bulk and incrementally cured composite resin. Eur J Prosthodont Restor Dent 2012;20(2):50–5.
68. Hummel SK, Marker V, Pace L, Goldfogle M. Surface treatment of indirect resin composite surfaces before cementation. J Prosthet Dent 1997;77(6):568–72.
69. Soares CJ, Soares PV, Pereira JC, Fonseca RB. Surface treatment protocols in the cementation process of ceramic and laboratory-processed composite restorations: a literature review. J Esthet Restor Dent 2005;17(4):224–35.
70. Spitznagel FA, Horvath SD, Guess PC, Blatz MB. Resin bond to indirect composite and new ceramic/polymer materials: a review of the literature. J Esthet Restor Dent 2014;26(6):382–93.
71. Roeder LB, Berry EA III, You C, Powers JM. Bond strength of composite to air-abraded enamel and dentin. Oper Dent 1995;20(5):186–90.
72. Freeman R, Varanasi S, Meyers IA, Symons AL. Effect of air abrasion and thermocycling on resin adaptation and shear bond strength to dentin for an etch-and-rinse and self-etch resin adhesive. Dent Mater J 2012;31(2):180–8.
73. Chee B, Rickman LJ, Satterthwaite JD. Adhesives for the restoration of non-carious cervical lesions: a systematic review. J Dent 2012;40(6):443–52.
74. Van Meerbeek B, Kanumilli PV, De Munck J, et al. A randomized, controlled trial evaluating the three-year clinical effectiveness of two etch & rinse adhesives in cervical lesions. Oper Dent 2004;29(4):376–85.
75. Belli R, Kreppel S, Petschelt A, et al. Strengthening of dental adhesives via particle reinforcement. J Mech Behav Biomed Mater 2014;37:100–8.
76. Castelnuovo J, Tjan AH, Liu P. Microleakage of multi-step and simplified-step bonding systems. Am J Dent 1996;9(6):245–8.
77. Wilder AD Jr, Swift EJ Jr, Heymann HO, et al. A 12-year clinical evaluation of a three-step dentin adhesive in noncarious cervical lesions. J Am Dent Assoc 2009;140(5):526–35.

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