Treatment of noncarious cervical lesions: when, why, and how

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Abstract

Noncarious cervical lesions (NCCLs) involve the loss of hard tissue from the cervical areas of teeth through processes unrelated to caries. NCCLs are nowadays a common pathology caused by changes in lifestyle and diet. The prevalence and severity of cervical wear increase with age. It is generally accepted that the lesions are not generated by a single factor but result from a combination of factors. Among the factors proposed to be related to the formation and progression of NCCLs are biocorrosion (erosion), friction (abrasion), and possibly occlusal stress (abfraction).

The clinical appearance of NCCLs can vary depending on the type and severity of the etiologic factors involved. Practitioners should follow a checklist to achieve an accurate diagnosis of the etiology of multifactorial NCCLs.

The successful prevention and management of NCCLs require an understanding of the etiology and risk factors, including how these change over time in individual patients. The decision to monitor NCCLs rather than intervene should be based on the progression of the lesions and how they compromise tooth vitality, function, and esthetics. Treatment options include techniques to alleviate dentin hypersensitivity and the placement of an adhesive restoration, eventually in combination with a root coverage surgical procedure. An adhesive restoration is considered the last treatment option for NCCLs.

Based on their excellent esthetic properties and good clinical performance, there is a general indication to place composite restorations for NCCLs. The clinical performance of these restorations is highly product-dependent, particularly regarding the adhesive system used. The type of composite material seems to have no significant influence on the clinical performance of NCCL restorations in clinical trials. It is much more important that the operator carries out the clinical procedure correctly. Marginal degradation is frequently seen during aging. Yearly maintenance with the eventual repolishing of the restoration margins will lengthen the lifespan of the restorations.

CLINICAL RESEARCH

Introduction

NCCLs are the result of a pathological condition characterized by the loss of tooth structure at the cementoenamel junction (CEJ) that is unrelated to dental caries. The occurrence of NCCLs is an increasingly common finding in dental clinical practice. This article aims to provide an up-to-date summary of the prevalence, appearance, and etiology of NCCLs. A checklist is presented to analyze the etiology of NCCLs. Also discussed are treatment possibilities based on current knowledge: prevention, monitoring, alleviation of dentin hypersensitivity, and treatment with an adhesive restoration.

Prevalence

The prevalence of NCCLs has been reported to vary between 5% and 85%. This large variation can be attributed to the wide age range of participants and the inclusion of both genders in study populations as well as the diverse criteria used to distinguish lesions caused by one precise etiologic factor.

A general finding is that prevalence, severity, and progression of NCCLs increase with age. This can be explained by extended exposure to etiologic factors, increased occurrence of gingival recession and bone loss with more root surface exposure (which raises the risk of cervical lesions), diminished quantity and quality of saliva, and compositional and microstructural changes of enamel and dentin.

NCCLs are almost exclusively situated on the facial surfaces of teeth; they seldom occur on the lingual surfaces and rarely on the proximal ones.

Fig 1. Extracted teeth showing different forms of NCCLs. (a) Cervical wear lesion on a mandibular central incisor mainly caused by erosion. Notice the poorly defined margins and adjacent smooth enamel surface. The lesion is most visible at the buccal side but is also present at the proximal and lingual sides. (b) Very deep NCCL with sharply defined margins on a maxillary premolar caused by a combination of abfraction (wedge shaped) and abrasion (notice the horizontal scratches in the depth of the lesion created by a toothbrush). The pulp is retracted and the dentin in the depth of the lesion is brown, discolored, and sclerotic. (c) U-shaped cervical wear lesion on a mandibular premolar caused by a combination of erosion and abrasion. The scratch in the depth of the lesion, created by the bristles of a toothbrush, is slightly smoothed by erosion. (d) Abfraction wedge-shaped lesion on retaining primary canine with sharp internal and external line angles and an apical extent relative to the CEJ. Notice the severe occlusal wear facet, which suggests abnormal occlusal loading.
Any tooth (incisor, canine, premolar or molar) may exhibit an NCCL. Several epidemiological studies have reported that premolars show the highest frequency of lesions. In some studies, the most commonly affected teeth were mandibular premolars, which also have the highest percentage of severe lesions.

### Appearance

Generally, NCCLs vary from shallow grooves or lesions with poorly defined margins to large wedge-shaped defects with sharp line angles (Fig 1a to d). A link between the morphological characteristics of lesions and their main etiologic factor has been suspected.

- **Disk-shaped broad and shallow lesions** with poorly defined margins and adjacent smooth enamel margins are considered to be the best predictive criteria for the diagnosis of erosion as well as a pathognomonic sign of erosive tooth wear (Fig 1a). In young patients with cervical erosive lesions, an enamel border is often noticed at the gingival margin (Fig 2a and b).
- **Lesions caused by abrasive forces** such as improper tooth brushing techniques generally exhibit sharply defined margins and a hard surface with traces of scratching (Figs 1b and 3).
- **Lesions caused by a combination of abrasion and erosion** often have a U shape (Figs 1c and 4).
- **Lesions caused by abfraction due to abnormal occlusal loading** are typically wedge shaped, with sharp internal and external line angles, and an apical extent relative to the CEJ (Figs 1d and 5).

![Image of tooth wear](https://example.com/image.png)
A common complaint of patients with erosive lesions is tooth hypersensitivity, an unavoidable problem if the corrosive challenge continues. In these lesions, dentin tubule exposure and enamel rod corrosion are widely reported.\textsuperscript{11}

**Etiology**

The development of a particular NCCL is usually the consequence of a synergistic action of two or three of the etiologic mechanisms unique to that individual case: biocorrosion (erosion), friction (abrasion), and stress (abfraction) (Figs 6 and 7). In addition, several risk factors can have an influence on the formation of NCCLs: saliva, tooth form, composition, microstructure, mobility, positional prominence, presence of restorations, magnitude, direction, frequency, site, and duration of the applied forces.\textsuperscript{4,13}

**Biocorrosion (erosion)**

Biocorrosion of teeth can occur due to extrinsic acids (acidic foods and drinks, acidic mouth rinse, acidic medication) and/or intrinsic acids (gastric acid). In addition, proteolytic enzymes present in the crevicular fluid\textsuperscript{14} and proteolytic enzymes from the stomach (pepsin) and pancreas (trypsin)\textsuperscript{15} released during vomiting can degrade the demineralized dentinal organic matrix.

Risk factors are the composition and frequency of the intake of acids, the position and form of teeth in the dental arch, and the presence of gingival recession. Saliva (pH, viscosity, flow, composition, buffer capacity) is an important risk factor in the development of NCCLs. The ions in saliva are able to induce remineralization of demineralized tooth structure and can thus inhibit the formation of NCCLs.

NCCLs are more common on facial surfaces of teeth than on lingual ones. A possible explanation is the difference in chemis-
try and character of saliva in lingual areas (more serous saliva – higher buffer capacity) and facial areas (mucous saliva – lower buffer capacity), which accounts for the differences in remineralization of the tooth structure and the dilution of buffering acids. Xerostomia and dehydration from perspiration with physical activity create impaired salivary flow and inhibit the buffering of acids in the oral cavity.

**Friction (abrasion)**

Friction or abrasion is the physical wear that results from a mechanical process involving foreign objects. Different factors can be involved such as abrasive toothpaste, improper tooth brushing using a horizontal technique and excessive force, frequency of brushing, stiffness of bristles, and particular dietary habits. The magnitude, direction, frequency, and duration of the applied forces are further risk factors in the development of NCCLs. In addition, a prominent position of the tooth in the arch leaves it prone to excessive forces from tooth brushing. From results of laboratory and clinical studies, there is little evidence that NCCLs are solely caused by abrasion.2

![Fig 6](image1) (a and b) Cervical lesions on all mandibular anterior teeth caused by a synergistic interaction of over-occlusion of the anterior teeth (abfraction), excessive tooth brushing (abrasion – notice the scratches on the surface of the lesion and gingival recession), and erosion. The patient is a vegetarian, which suggests the influence of an abrasive and erosive factor. Brown, discolored sclerotic dentin is present on all the lesions.

![Fig 7](image2) (a to c) Generalized extensive NCCLs in a 62-year-old male patient. Examination pointed to a multifactorial etiology. The occlusal surfaces showed wear facets with erosive cupping. The patient’s diet consists of many abrasive foods and he is extremely fervent when cleaning his teeth, resulting in extensive forces being applied during tooth brushing. Notice pronounced gingival recession and a traumatized gingiva in the maxillary anterior region. The cervical lesions in the mandible are shallower, probably because of their more lingual position. Sclerotic dentin is present in most lesions.
Stress (abfraction)

The abfraction theory is based on a biomechanical concept in which the cervical area of a tooth becomes a fulcrum during occlusal function, bruxing, and parafunctional activity, causing tensile stresses in the area where NCCLs occur. These stresses are thought to disrupt the crystalline structure of the locally thin enamel and underlying dentin by cyclic fatigue, leading to cracks. Ultimately, the enamel breaks away at the cervical margin and progressively exposes the dentin, where the process continues. This theory is quite controversial. Several finite element analysis (FEA) studies have shown a clear correlation between occlusion and NCCLs. In addition, several clinical trials also report strong evidence of an association between occlusal factors and NCCLs (or their progression); nevertheless, two systematic reviews were unable to show a clear association. The large heterogeneity among methodologies, the lack of standardization, and differences in the diagnoses of NCCLs could contribute to the weak evidence in these two reviews, both of which concluded that prospective clinical studies with a qualitatively and quantitatively strong study design are needed to prove a clear association between occlusion and NCCLs.

According to Grippo et al., some risk factors can play a role in the development of abfraction lesions. First, resultant stresses within the teeth are dependent on the magnitude, direction, frequency, site of application, and duration of a force, in addition to its orientation with respect to the principal axes of the teeth and their form, composition, and stability. Second, the cushioning effect of the periodontal ligament is another modifying factor, as there is a negative correlation between mobility and NCCLs. Third, the weakening effect of an occlusal restoration may contribute to the development of an abfraction lesion. Finally, the occlusal positional prominence of the teeth is another important factor in determining possible overstress and trauma (Fig 8).

Most lesions are caused by an interaction of two or three causes that result in increased cervical tooth wear, ie, the combined effect of erosion and abrasion is greater than the effect of either force operating on its own. It also appears that liquid acid, frequently found in modern diets, may be necessary in order for occlusal loading to be a factor in the formation of cervical lesions. In addition, it is suggested that biocorrosion plays a very important role in the formation of NCCLs.

Clinicians should consider all etiologic and risk factors before completing the diagnosis or initiating treatment, if indicated. Practitioners should follow a checklist to determine the etiology of each particular lesion in order to make as precise a diagnosis as possible. Table 1 shows a simplified version of the schema proposed by Grippo et al.

Treatment options

To date, there is no conclusive evidence for reliable, predictable, and successful treat-
## Biocorrosion – erosion
### Chemical, biochemical, and electrochemical degradation of enamel and dentin

<table>
<thead>
<tr>
<th>Check</th>
<th>Etiologic factors</th>
<th>Risk factors</th>
</tr>
</thead>
</table>
| Diet  | • Acidic beverages and foods  
• Citrus fruits and juices | • Composition and frequency of intake of acidic foods and drinks  
• Buffering capacity, composition, flow rate, pH, and viscosity of saliva  
• Position and form of the teeth in the dental arch  
• Gingival recession |
| Profession | • Wine tasting  
• Occupational exposure to acidic industrial gases  
• Activities resulting in dehydration (eg. sport activities) | |
| Medical history | • Gastroesophageal disease with reflux  
• Anorexia or bulimia nervosa  
• Factors predisposing the patient to gastric reflux (eg. hiatus hernia, sport activities)  
• Acidic medication (eg. Vitamin C)  
• Acidic mouth rinses  
• Medication that decreases salivary flow | |

## Abrasion – friction
### Physical wear as a result of a mechanical process involving foreign objects

<table>
<thead>
<tr>
<th>Check</th>
<th>Etiologic factors</th>
<th>Risk factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diet</td>
<td>Mastication of coarse foods</td>
<td></td>
</tr>
</tbody>
</table>
| Oral hygiene practices | • Abrasive toothpaste  
• Tooth brushing technique  
• Stiffness of toothbrush bristles  
• Frequency of brushing  
• Incorrect hygiene habits | • Magnitude, direction, frequency, site, and duration of force applied during tooth brushing  
• Position and form of the teeth in the dental arch  
• Gingival recession |
| Dental appliances | Clasps of prostheses | |

## Abfraction – stress
### Tensile stress at the cervical area during occlusal loading

<table>
<thead>
<tr>
<th>Check</th>
<th>Etiologic factors</th>
<th>Risk factors</th>
</tr>
</thead>
</table>
| Occlusal examination | • Parafuction (eg, bruxism, clenching)  
• Excessive functional load  
• Malocclusion  
• Premature contacts  
• Eccentric loading  
• Habits (eg, biting on hard objects)  
• Mastication of hard and resistant food substances | • Magnitude, direction, frequency, site, and duration of the applied forces  
• Mobility of the teeth  
• Presence of occlusal restorations |
ment regimens for NCCLs. The current knowledge and available treatment strategies for NCCLs are discussed below, with a focus on prevention, monitoring, treatment of dentin hypersensitivity, restorative treatment, and root coverage surgical procedures with or without restorative treatment.

**Prevention**

The objectives of preventive therapy are to prevent the progression of existing lesions or the development of new ones and to assure the longevity of restorations in restored lesions. Preventive interventions include counseling for changes in the patient’s behavior depending on the etiology (abrasion, erosion, and/or abfraction).

Cervical abrasions are generally thought to be a consequence of tooth brushing factors such as frequent or forceful brushing, faulty or vigorous techniques, filament stiffness or design, dominant hand dexterity, or abrasive dentifrices. Patients should be informed about these factors and, where necessary, advised to alter their brushing materials or habits. In addition, patients should be instructed to avoid brushing immediately after an erosive challenge.

Dental erosion can also be effectively modified and should be correctly diagnosed. Treatment success depends on the patient’s collaboration. When erosion is caused by eating disorders or gastroesophageal reflux disease, the treatment may require the participation of a physician. The extrinsic etiology is more easily treatable. During the diagnostic phase, the checklist (Table 1) must be followed to see which external erosive factors exist. Removing or altering harmful habit/s provides consistent results.

For NCCLs with an abfraction etiology, there is no consensus on preventive treatment strategies. On the one hand, there is a weak association between NCCLs and occlusal factors (interference in excursive movements, force, premature contacts, type of guidance, and slide of centric occlusion to maximum intercuspation). In two systematic reviews, several authors advise that any decision to carry out a destructive, irreversible treatment such as occlusal adjustment should be considered very carefully. If abfraction is suspected to be a dominant factor in the etiology of NCCLs, the most conservative treatment option suggested is an occlusal splint as this reduces the amount of nocturnal bruxism and nonaxial tooth forces, although in this case too there is no scientific evidence to support the use of an occlusal splint. On the other hand, Soares and Grippo state that preventive management strategies should consider occlusal therapy in patients with parafunctional habits and occlusal prematurities. According to these authors, occlusal therapy can mitigate the development of NCCLs by correcting occlusal imbalance and removing occlusal prematurities. They emphasize that occlusal therapy must be carried out with a thorough knowledge of the occlusion.

**Monitoring**

The activity of NCCLs needs to be assessed and considered in the treatment planning process. It is known that the progression of NCCLs is generally slow, but with a large variation among patients. Therefore, an individual monitoring protocol should be established that assesses the severity of the present lesions, the patient’s age, and the existing etiologic and risk factors. For patients who are exposed to intrinsic acids or who present with rapid progression, the assessment procedure of lesion activity should be repeated at 6-month intervals during regular hygiene. For most other cases, annual assessment is acceptable (Fig 9).

Approaches to determine lesion activity include the use of standardized intraoral
photographs, possibly study models, and the measurement of lesion dimensions (width/length) over time. With the recent introduction of digital dentistry, computer-aided design/computer-aided manufacturing (CAD/CAM) systems may be useful for the diagnosis of NCCLs and in monitoring their activity.

In a prospective clinical trial evaluating the progression of NCCLs over a 5-year period, the rate of progression was significantly related to mean occlusal stress and relative occlusal force in the maximum intercuspation position. No significant correlation was found between NCCL progression and a more acidic diet, tooth brushing technique/rigorousness, medical conditions causing deficient or acidic saliva output, presence of occlusal wear facets, group function, or adverse oral habits. Moderate sensitivity on the involved teeth was found in 34.5% of the participants by using the cold test. A moderate to high degree of sclerosis was observed on 68.9% of the lesions.

In another in vivo study evaluating 10 lesions in six patients over a period of 4 to 5 years, dimensional analysis showed notable progression in deeper lesions. In addition, wedge-shaped lesions were reported to progress at a greater rate compared with saucer-shaped ones. The same observation was made in an in vitro study using 3D FEA. V-shaped lesions showed higher stress levels concentrated at the zenith of the lesion, whereas in U-shaped defects the stresses were concentrated over a wider area. As the lesions advanced in depth, the stress was amplified at their deepest part. A trend of stress amplification was also observed with decreasing bone height.

One should bear in mind that restorative treatment may be indicated at an earlier stage for V-shaped lesions than for U-shaped ones in patients with a heavy occlusion and articulation. Restoring deeper (1.5 mm) NCCLs is usually prioritized over shallower ones due to the higher stress development of deeper lesions that results in their more notable progression.

**Treatment of dentinal hypersensitivity**

Dental hypersensitivity is a symptom often associated with early stages of NCCLs. If the lesions are small and shallow and require no restorative treatment, and should sensitivity persist, the hypersensitive tooth must first be treated in a noninvasive way. There is a broad spectrum of relatively cost-effective at-home desensitizing agents available on
hypersensitivity and promote remineralization of the tooth surface, e.g., Teethmate Desensitizer (Kuraray Noritake) (Fig 10) and air polishing with Sylc Bioactive Glass (Velopex) (Fig 11a to d). These products react with body fluids and result in the formation of hydroxyapatite (HAp) crystals, similar to the minerals in dentin, which block the dentinal tubules. Both systems show promising results; however, confirmation in clinical trials is required.

Finally, resin-based dental adhesive systems can also provide a longer-lasting dentin-desensitizing effect compared with the use of home-desensitizing agents. The adhesive resins can effectively seal the dentinal tubules by forming a hybrid layer. Various clinical studies have demonstrated the effectiveness up to 6 months of adhesives in the management of dentin hypersensitivity.

**Restorative treatment**

Restorative treatment of NCCLs should be considered when one or more of the following conditions are present: 1) active, cavitated caries lesions associated with NCCLs; 2) cervical lesion margins or all lesion margins are located subgingivally and preclude plaque control, hence the risk of caries and periodontal disease increases; 3) extensive tooth structure loss, which compromises the integrity of the tooth, or the defect is in close proximity to the pulp, or the pulp has been exposed; 4) persistent dentinal hypersensitivity in which noninvasive therapeutic options have failed; 5) prosthesis abutment for removable prosthesis; and 6) esthetic demands by patients. If there is a need for a restoration, NCCLs should be restored as minimally invasively as possible. Of the available restorative techniques, an adhesive system, combined with a composite resin, is the preferred choice of practitioners due to the good esthetic prop-
A female patient with extensive cervical abrasion lesions on all her teeth. The exposed dentin surfaces showed hypersensitivity. At-home desensitizing therapy did not give relief from hypersensitivity. Therefore, in-office therapy – air polishing with Sylc Bioactive Glass (Velopex) – was planned. (b and c) After local anesthesia, air polishing of the exposed root surfaces with bioactive glass was carried out, using a pressure of 4 to 5 bars with water spray 1 to 2 mm away from the surface. The orientation of the spray is 45 to 90 degrees. The action is to move slowly for about 30 to 60 s, as if painting the surface. (d) Air polishing with bioactive glass resulted in a serious reduction in dentin hypersensitivity. In a next step, cervical composite restorations will be placed, followed by a root coverage surgical procedure (CTG and CAF).
Fig 12  (a) A 70-year-old female patient showing NCCLs on all her mandibular anterior teeth. The etiology was multifactorial, with abrasion being the main etiologic factor. The exposed dentin was not hypersensitive. The reason for the treatment with direct composite restorations was to improve esthetics. (b) Apart from the small lesion on tooth 43, all the NCCLs were restored with a nanohybrid composite in combination with a mild 2SEa.

Fig 13  Two mandibular premolars with 20-year-old Class V composite restorations. A 3E&Ra adhesive system was used in combination with a microfilled composite (first premolar) and a hybrid composite (second premolar). After 20 years, the restorations are still clinically acceptable, presenting slight marginal defects and superficial marginal discoloration.

...erties and clinical performance of composite resin (Fig 12). Although glass-ionomers, resin-modified glass-ionomers, and the lamination technique with composite resin have been advocated for NCCL restorations, these materials are less frequently used.\(^{42,43}\)

Adhesively restored NCCLs can perform quite well in the long term (Fig 13).\(^{43}\) Several parameters determine the clinical behavior of these restorations. According to a systematic review evaluating the clinical effectiveness of contemporary adhesives in NCCLs, the selection of the adhesive system is an important factor determining the durability of the restoration.\(^{43}\) Apart from the selection of the adhesive system, the operator plays a decisive role. The operator has to take care that a high-quality clinical procedure is carried out: isolation, tooth preparation, application of the adhesive system and composite, finishing, polishing, and finally maintenance of the restoration. These different parameters are successively discussed in detail below.

**Selection of the adhesive system**

According to the classification of Van Meerbeek et al.,\(^{44,45}\) modern adhesive approaches can be divided into etch-and-rinse adhesives (E&R), self-etch adhesives (SEa), and restorative materials with a self-adhesive approach (Fig 14).

The multi-step *etch-and-rinse* approach involves a phosphoric acid-etch step that at the enamel level produces deep etch pits in the HAp-rich substrate, and at the dentin level demineralizes up to a depth of a few micrometers to expose a HAp-deprived collagen mesh. The next step involves either a separate priming step followed by the application/curing of a combined primer/adhesive resin using a 2-step procedure (2E&R), or a separate primer and adhesive resin following a 3-step procedure (3E&R). The final objective is to micromechanically interlock
upon diffusion and in situ the polymerization of monomers into the enamel etch pits, the opened dentin tubules, and the exposed collagen network, the latter forming the well-documented hybrid layer.44,45

Self-etch adhesives use non-rinse acidic monomers that simultaneously condition and prime dentin. Self-etching only dissolves the smear layer but does not remove the dissolved calcium phosphates as there is no rinse phase. The clinical application time is shorter, and technique-sensitivity is reduced. In addition to a 2- and 1-step procedure (2SEa, 1SEa) – depending on the use or not of a separate solvent-free bonding agent – a further distinction can be made depending on the pH of the self-etching primer: strong (pH < 1) (SEA_s), intermediate (pH ± 1.5), mild (pH ± 2), and ultra-mild (pH ≥ 2.5). The latter three groups (intermediate, mild, ultra-mild, named below as SEA_m) do not demineralize the dentin surface completely, and HAP will be left in the hybrid layer. The functional monomer (e.g., 4-MET, 10-MDP, phenyl-P) present in the self-etching primer has the possibility of chemically interacting with the HAP.46 This results in a twofold micromechanical and chemical bonding mechanism. Of all commercially available functional monomers, 10-MDP has been proven to be the most effective one, able to form a stable and durable chemical bond with HAP in the hybrid layer.47 E5Ra and SEa are combined with a restorative material (a composite resin, a gionomer or a compomer).

Glass-ionomers (GIs) and resin-modified GIs are self-adhesive materials. A short polyalkenoic acid pretreatment is recommended, resulting in a 2-step approach. The polyalkenoic acid conditioners clean the tooth surface. It removes the smear layer and exposes collagen fibrils up to a depth of about 0.5 to 1 μm, where GI components inter-diffuse and a micromechanical bond is established following the principle of hybridization. Chemical bonding is additionally obtained by ionic interaction of the carboxyl groups of the polyalkenoic acid with the calcium of the HAP that remains attached to the collagen fibrils. Most of the glass-ionomers and resin-modified glass-ionomers are available as restorative materials.

Other self-adhesive materials are the so-called self-adhesive luting composites, most of which are available as luting agents. Self-adhesive flowables were introduced onto the dental market some years ago, but the in vitro bonding efficiency to tooth structure is below the level of that recorded for the commonly used adhesive systems described above.48

Nowadays, there is a major trend to use universal adhesives, which are actually a

![Classification of contemporary adhesives according to Van Meerbeek et al.44,45](image)
newer version of 1SEa_m that can be applied in different modes: an etch-and-rinse mode, a self-etch mode, and a self-etch mode with prior selective etching of the enamel margin with 35% phosphoric acid.59,50

NCCLs are the most ideal lesions to test the clinical effectiveness of adhesives in clinical trials.43 These lesions involve both enamel and dentin; however, the largest part of the tooth structure on which to bond consists of dentin. These lesions commonly do not provide any (or they provide minimal) macroretention, so ineffective bonding will result in debonding and thus restoration loss. Loss of retention is the key objective parameter against which the bonding performance of adhesives in NCCL clinical trials is evaluated. In a systematic review of NCCL clinical trials, the number of lost restorations per year (calculated as annual failure rate [AFR]) was recorded in 87 clinical trials evaluating 78 different adhesives.44 The adhesives were classified into seven different classes: 3E&R, 2E&R, 2SEa_m, 2SEa_s, 1SEa_m, 1SEa_s, and GI. 5Ea_m contains the intermediate, mild, and ultra-mild SEa (described on the previous page). The first conclusion was that the adhesive strategy is a determining factor for the clinical bonding effectiveness in NCCLs. The best-performing classes were GI, with the lowest AFR score, followed closely by 2SEA_m, 3E&R, and 1SEA_r11. An inadequate bonding effectiveness was noticed for 2E&Ra, 1SEa_s, and 2SEa_s. It is obvious that the chemical bonding potential of adhesives is important for the quality and durability of the bond in NCCLs. In addition to the adhesive strategy, a wide variation exists between the adhesives themselves. Practitioners should therefore select a product that has a good proven clinical performance. In the best-performing adhesive categories described above, the lowest AFR scores were recorded for Optibond FL (Kerr) for 3E&Ra, Clearfil SE Bond (Kuraray Noritake) for 2SEa_m, and G-Bond (GC) for 1SEa_m. These results accord with those of a systematic review that evaluated the bonding effectiveness of adhesives in vitro according to microtensile bond strength tests.51 Similarly, Optibond FL and Clearfil SE Bond showed the best results regarding immediate bond strength and bond strength after 1 year of water storage.

Although GI-based materials perform well with regard to retention, their rather poor esthetic properties, inferior wear resistance, and solubility particularly in acidic oral environments may make them less adequate for restoring NCCLs, especially in the anterior and premolar regions.42,43

Isolation

Proper isolation is important for the success of NCCL restorations. A recently published meta-analysis stated that the use of rubber dam positively influences the performance of adhesive NCCL restorations, resulting in less retention loss and better marginal adaptation.52 Therefore, if the clinical situation allows, absolute isolation with rubber dam should be applied. A good strategy has to be followed, with the practitioner aware of the tips and trips to correctly isolate under rubber dam.53 For this procedure, the use of heavy rubber dam is preferred as it results in the best retraction of the peripheral tissues, including the papilla. The holes must be punched correctly so that all gingival tissues are covered. Inverting the rubber dam around the neck of the tooth prevents the saliva from leaking in between the rubber dam and the gingiva. Useful clamps for rubber dam isolation of NCCLs are the Brinker Clamps (Tissue Retractors) (B4, B5, B6) (Hygenic; Coltene Whaledent) and Clamp 212 (Hu Friedy). In addition, floss, teflon tape, and gingival retraction cord can be used to obtain additional gingival retraction (Figs 15 and 16).

Intrinsic anatomical and morphological characteristics of the cervical region can cre-
ate limitations in the placement of the rubber dam and clamp. Difficulties can occur, for instance, when restoring a NCCL on a molar or on other teeth with a very large difference in height between the buccal and lingual gingiva or when teeth are severely crowded.

When adequate rubber dam isolation is not possible, another isolation method should be employed. The insertion of a gingival retraction cord in combination with cotton rolls can help to control moisture. A blood and hemostatic agent can be used when needed to control blood contamination. Some studies have demonstrated that dentin contamination with ferric sulfate or aluminum chloride decreases the bond strength of self-etch adhesives.\textsuperscript{34,35} Grodeck\textsuperscript{e} et al\textsuperscript{36} showed that cavity contamination with hemostatic agents, applied after blood contamination and removed with water spray, does not compromise marginal adaptation in enamel and dentin when using an E\&Ra or an SE\textsubscript{a},\textsuperscript{36} although element surface analysis showed that remnants of hemostatic agents were found on enamel and dentin surfaces after rinsing the dark coagulum with water spray. Apparently, remnants of hemostatic agents on the surface of dental hard tissues might have less influence on marginal adaptation than on bond strength. A last option is a proposed association of a plastic or metal matrix with wooden wedges and a photopolymerized gingival barrier.\textsuperscript{37}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{image}
\caption{Tooth preparation}
\end{figure}

\textbf{Tooth preparation}

\textit{Preparation of the enamel side}

At the incisal side, the composite material will be bonded to enamel. A short enamel bevel (1 to 2 mm) should be prepared using a microfine diamond bur (Fig 16a). This re-
moves the aprismatic enamel and increases the bond strength to enamel. In addition, placement of an enamel bevel will result in a more gradual transition between the composite restoration and tooth surface, improving the final esthetic outcome.

**Preparation of the dentin surface**

The dentin surface of NCCLs is often sclerotic and is a more difficult substrate to bond to than sound dentin. Sclerotic dentin is hypermineralized and has a shiny and firm appearance. The dentin tubules are partially or completely occluded by mineral deposits, resulting in a higher resistance to acid dissolution. Morphological evaluation of the resin–sclerotic dentin interface shows a thin hybrid layer at the hypermineralized intertubular dentin, and short and barely developed resin tags.

To increase the bonding effectiveness to this type of dentin, the superficial sclerotic dentin should be roughened with a diamond bur (Fig 16a). Another important reason to roughen the dentin surface is to remove the contaminated layer observed on most NCCLs during microscopic evaluation of extracted teeth (Fig 17). This layer resists adhesion and should therefore be removed.

The roughness of the diamond bur is important as this can influence the thickness of the smear layer. The creation of a thick smear layer can interfere with the bonding efficiency of mild/ultra-mild (pH ≥ 2) self-etch adhesives. Therefore, to ensure a clean roughened tooth surface with a minimal thickness smear layer, tooth preparation should be finalized using airborne-particle abrasion with Al₂O₃ powder (27 or 50 μm) (Fig 16b). Air abrasion is reported to increase the surface area available for adhesion, improve resin adaptation, and enhance resin tag formation. Several *in vitro* studies have shown an increased bond strength to dentin when using an E6Ra or SEa. Other *in vitro* studies, however, measured no significant influence of air abrasion on the bond strength to enamel and dentin (also for E6Ra and SEa), not even after aging.

In general, the preparation must be kept as minimally invasive as possible by only roughening the enamel and dentin surfaces. However, in sharp, wedge-shaped NCCLs in teeth with heavy occlusal loading, rounding the depth of the angular lesion can be justified to improve the biomechanical behavior of the restorative material and consequently promote clinical longevity (Fig 16).

**Application of the adhesive system**

The adhesive system must be applied strictly according to the manufacturer’s instructions (Figs 18 to 20). When using a non-simplified adhesive (3E6Ra, 2SEa), the primer must be applied vigorously and rigorously to the dentin surface for the amount of time indicated by the manufacturer. An optimized wetting and penetration of the exposed dentin surface will result in the formation of a good-quality hybrid layer. The importance of this step is often underestimated.

When using a mild SEa system, the best clinical performance will be obtained when the incisal enamel is selectively etched with 35% phosphoric acid (Fig 18). Small marginal
Fig 18  (a) Tooth 31: Selective enamel etching of the prepared enamel with phosphoric acid (35%) for 20 s to optimize the bonding at the incisal enamel side. (b) After rinsing with water and drying, a dull-etched enamel surface is clearly visible.

Fig 19  (a) Tooth 31: Application of a 10-MDP-containing self-etching primer (Clearfil SE Bond 2; Kuraray) for 20 s. (b) The primed surface was air dried gently and slightly until a dull surface was noticed.

Fig 20  (a and b) Teeth 44 and 31: The adhesive was applied, air thinned, and light cured for 10 s.
defects and superficial marginal discoloration will present less frequently at the incisal enamel side with aging. Etching enamel with phosphoric acid creates a deeper and more pronounced etch pattern compared with SEa and results in an increased micromechanical retention and a more optimal bond to enamel.

Selecting a universal adhesive, a 10-MDP-based adhesive is preferred, used in a self-etch mode with prior selective etching of the enamel. The chemical interaction between the 10-MDP functional monomer and calcium is only possible when HAp remains in the hybrid layer. All HAp is dissolved when one follows the E&B approach.

Finally, when using a simplified adhesive system, it is best to cover the adhesive with a hydrophobic resin coating. The use of this additional coating after the application of a simplified adhesive system leads to a thicker and more uniform adhesive layer with less retained water and solvent and a significant reduction in the fluid flow rate. In this way, a more stable resin–dentin interface is formed.

Selection and application of the composite

Selection of the composite

NCCLs have a relatively small C-factor, meaning that the mechanical properties of the composite are less important to the outcome of the final restoration than the actual performance of the adhesive. Indeed, several reviews have shown that the type of composite used had no influence on the bonding performance of adhesives in NCCLs. Similarly, compomers and giomers, both fluoride-releasing resin materials, do not show a better performance compared with conventional composites in NCCL clinical trials.

It has been stated that NCCLs suspected of being caused primarily by abrasion should be restored with a microfilled resin composite or a flowable resin that has a low modulus of elasticity because these will flex with the tooth and not compromise retention. However, no definitive conclusion can be found in the literature that addresses the difference between failure rates of resin composites of different stiffness used to restore NCCLs.

Application of the composite

A multiple layering technique with a conventional composite has been proposed to restore deeper and/or larger lesions to minimize shrinkage due to polymerization and also to achieve better marginal adaptation in Class V non-carious lesions. Several in vitro studies have shown that the best results are obtained when using the oblique layering technique from gingival toward incisal. This technique has been applied in most NCCL clinical trials. Indeed, since enamel adhesion is stronger, more stable, and more predictable, the insertion of material should begin from the gingival wall, without the surrounding enamel. Whenever possible, the cavity should be restored with three or two increments (Figs 21 to 25). The last one should be placed on the enamel margin. Small lesions can be restored with one increment.

An alternative application method is to cover the entire exposed dentin surface with a thin layer of flowable composite in a first step to optimize the adaptation of the composite to the hybridized dentin surface. In addition, the lower e-modulus and higher flexibility of the flowable composite will compensate for polymerization shrinkage. Next, the rest of the lesion should be restored with a stiffer conventional composite (Figs 24 and 25).

As far as esthetics is concerned, the color of the cervical area is easy to obtain. The use of a medium opacity chromatic dentin composite covered with a more translucent slightly chromatic enamel composite – also
Fig 21  (a) Tooth 44: Application of a chromatic dentin composite covering the dentin surface (Essentia Dark Dentin; GC) followed by polymerization. (b) Next, a translucent enamel composite with low chromaticity, also called achromatic enamel⁵ (Essentia Dark Enamel) was applied to restore the contour of the tooth. This layer covers the incisal enamel bevel.

Fig 22  (a) Application of glycerine gel and final polymerization (20 s) to eliminate the oxygen-inhibited layer. (b) The restorations were checked 1 week after final finishing and polishing.
Fig 23  NCCLs on teeth 44, 42, 41, and 31 (a) before and (b) after placement of direct composite restorations.

Fig 24  NCCLs on teeth 34 and 35 (a) before and (b) after restorative treatment with direct composite restorations.

Fig 25  (a) Tooth 35: Application of the adhesive system. (b) A thin layer of flowable composite was applied over the whole dentin surface and polymerized. (c) A conventional microhybrid composite was placed to restore the original contour, starting from the cervical third and covering the incisal enamel margin.
called achromatic enamel\textsuperscript{76} – copies the natural tooth structure (Figs 21 to 23). Most practitioners prefer a simplified color build up and use just one chromatic body composite with medium opacity.

A careful placement technique is needed to minimize the finishing procedure.

**Finishing and polishing**

Any excess or roughness should be avoided in NCCL restorations. Plaque retention, gingival inflammation, and the occurrence of caries lesions represent not only a failure of the restoration but also a creation of new problems for the patient. Poorly performed finishing and polishing procedures can lead to soft and hard tissue damage. Techniques that require a minimal amount of finishing and polishing are ideal, but properly contoured restorations are seldom achieved without removing excess material, especially at the margins. When needed, a good option is to use a microfine diamond finishing point (40 μm grit size), then a coarse composite finishing disc, and finally the application of rubber polishing points with a decreasing grit size (Fig 26).

When a Class V restoration is performed in a semi-direct way, as described by Fahl\textsuperscript{6} and Ritter et al.,\textsuperscript{77} the composite restoration is made and finished extraorally and is then bonded with a luting composite. The extraoral finishing and polishing of these Class V inlays simplify the finishing procedure of the restoration after cementation. According to these authors, this technique more easily provides a high surface smoothness and a good marginal adaptation compared with the commonly used direct technique. However, clinical studies are required to prove whether this technique is superior to the clinically proven direct technique.

**Maintenance**

The condition of the restorations must be evaluated yearly. Marginal deterioration that presents as marginal discoloration and small marginal defects is commonly seen in these restorations with aging.\textsuperscript{43,78} Their lifespan can be lengthened by repolishing the restor-

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**Fig 26** Finishing and polishing of NCCL composite restorations. (a) Using a microfine pointed diamond bur (40 μm). (b and c) Finally, polishing with rubber polishing points with a decreasing grit size.
Fig 27  (a) A female patient requested the replacement of cervical composite restorations due to discolored margins. (b) Repolishing the restoration margins removed the superficial discoloration, thus increasing the longevity of the restorations.

If larger defects are present, local repair is indicated.

The influence of the patient factor on the clinical performance of the restorations should not be underestimated. As already mentioned, the etiology of the NCCLs must always be kept under control to prevent recurrence of the lesions. Importantly, special conditions such as poor oral hygiene, high caries risk, heavy bruxism, and erosive challenges were not included in most NCCL clinical trials. Although one expects that these high-risk patient factors negatively influence the lifespan of the restorations to a large extent, the clinical longevity of resin composites as restorative materials in such a context has not yet been clinically investigated.

Root coverage surgical procedures in combination with a restoration

NCCLs may be associated with gingival recession, exposing root surfaces to the oral cavity. Placement of a composite restoration is possible, but the esthetic result can be disappointing. If esthetics is important to the patient, the ideal treatment for the combination of noncarious cervical lesions (particularly in the case of deep lesions) and gingival recession is a combined perio-restorative approach (Fig 28). In a combined restorative-surgical approach, the restoration must be placed prior to the surgical procedure for better visibility of the operative field and for the finished restoration. To properly restore the dental tissue lost due to wear, the maximum level of root coverage needs to be predetermined.

The restoration should recreate not only the contour of the tooth crown but also that of the lost CEJ at the root portion. Recent systematic reviews have pointed out that the combination of a coronally advanced flap (CAF) with connective tissue graft (CTG) provides the best clinical outcomes for root coverage when appropriately performed. However, there is still a lack of long-term clinical evidence to prove the stability of the combined perio-restorative approach.

Conclusion

To achieve an accurate diagnosis of the etiology of multifactorial NCCLs, practitioners should follow the following checklist: comprehensive medical and dental history, occlusal examination, evaluation of diet, and oral hygiene procedures. Furthermore, important risk factors in the formation of NCCLs should be taken into account.

Treating NCCLs necessarily involves problem identification, diagnosis, etiologic factor removal, monitoring, and, if necessary, treatment. Personalized treatment
Fig 28  (a) Initial situation: A 50-year-old female patient showed gingival recession on the maxillary anterior teeth and deep cervical lesions on the maxillary premolars and first molars. The patient requested an esthetic improvement. The deep defects on teeth 14, 15, 16, and 26 were first restored with direct composite restorations until the level of the C.E.J. (b) Initial situation: Lateral view, with NCCLs on several teeth. (b) After placement of direct composite restorations on teeth 14, 15, and 16 (restoring deep defects). (c and d) Further esthetic improvement was realized by surgical root coverage of the cervical lesions (combination of CTG and CAF) on teeth 13, 14, 15, 16, 21, 23, and 26. (e) Final result after surgical root coverage of the cervical lesions (combination of CTG and CAF) on teeth 13, 14, 15, and 16.
should be applied, with the appropriate approach adopted for the specific situation. Particular attention should be paid to the preventive phase, as this will also determine the longevity of the restorative treatment. When function and esthetics are impaired, direct composite restorations are indicated to restore deep lesions. These restorations show an acceptable clinical performance in the long term provided an adhesive system with a good proven clinical performance is selected. In addition, a high level of operator skill combined with a careful operative procedure is required to enhance the longevity of the restorations.

In case NCCLs are associated with gingival recession, the original soft and hard tissue relation and structure can be restored esthetically and functionally by a combined perio-restorative intervention.

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