Clinical effectiveness of self-etching adhesives with or without selective enamel etching in noncarious cervical lesions: A systematic review

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Abstract Background/purpose: Noncarious cervical lesions (NCCLs) are among the most frequent conditions requiring resin restorations. However, the major shortcoming of these restorations is limited longevity. The purpose of this study was to compare the clinical performance of self-etching (SE) adhesives with or without selective enamel etching in NCCLs.

Materials and methods: An initial literature search, with strict inclusion and exclusion criteria, was conducted in MEDLINE, Web of Science, the Wiley Online database, and the Cochrane Controlled Trials Center. Eight trials were included. Restoration retention, prevalence of marginal defects, and marginal discoloration were evaluated. Data were analyzed using the Mantel–Haenszel method with 95% confidence intervals.

Results: Results demonstrated that fewer marginal defects (P = 0.0001) and discoloration (P = 0.008) were observed with the selective enamel etching approach. The risk ratio (RR) values of the selective etching group and the nonselective etching group for marginal defects and discoloration were 0.58 (0.44, 0.77) and 0.48 (0.28, 0.83), respectively. For restoration retention, the differences between the two groups were not significant (P = 0.44). The RR values of the selective etching group and the nonselective etching group for...
Introduction

Noncarious cervical lesions (NCCLs), which may be caused by erosion, abrasion, or occlusal stress, are among the most frequent situations requiring adhesive techniques in modern operative dentistry. It is necessary to restore NCCL to relieve hypersensitivity, to prevent further tooth structure damage, and to improve the esthetics. However, loss of retention and marginal discoloration are the main shortcomings of NCCL in adhesive technology. In NCCL, restorations are placed on nonretentive cavities, and the dentin exhibits a high degree of sclerosis with large amounts of minerals, rendering the establishment of a hybrid layer more difficult. In addition, NCCLs have poor long-term prognosis because of the large proportion of dentin margins and the high stress concentrated on the cervical area. Because the prevalence of NCCL likely increases with older age, improvement in clinical longevity of resin restorations is an urgent necessity that would benefit public oral health.

In NCCL, the major part of the bonded tooth surface consists of dentin, and requires at least 50% surface bonding to dentin when restored. Mostly, the adhesive restorative material is bonded to enamel, as well as to the dentin margins on the incisal side. Because no delicate rinsing step is required, self-etching (SE) adhesives present various advantages over total-adhesive procedures: they are less technique sensitive and less time consuming, and they are expected to induce less postoperative sensitivity. However, unlike bonding to dentin, the strength and longevity of adhesion to enamel using SE adhesives have been controversial issues. The etching pattern of enamel using SE adhesives appears to be less retentive than that produced by phosphoric acid. As a result, selective etching of enamel with phosphoric acid prior to the application of dentin adhesives has been proposed to improve the durability of the enamel bond. Miyazaki and colleagues suggested that previous etching of enamel with phosphoric acid could provide greater bonding strength to enamel and better marginal sealing ability of restorations. Indeed, clinical effectiveness can be defined as “the extent to which a treatment achieves its intended effect in the usual clinical setting”. According to the modified United States Public Health Services (USPHS)/Ryge criteria for restoration evaluation, clinical effectiveness is recorded in terms of retention, marginal integrity (absence of major or minor marginal defects), marginal discoloration, caries recurrence, preservation of tooth vitality, and postoperative sensitivity. In a review article by Heintze et al., the first three (retention, marginal integrity, and marginal discoloration) were considered the “key” parameters of clinical effectiveness in determining the “overall clinical success rate”. The American Dental Association (ADA) previously defined an adhesive system as having “full acceptance” if the retention rate was greater than 90% after an observation period of 18 months and if the loss of retention rate was less than 20% after 3-year follow up.

The aim of this review was to compare the clinical effectiveness of SE adhesives, with or without previous enamel beveling and selective phosphoric acid etching, in restorations of NCCL. Data were assessed by meta-analysis, which is a robust statistical methodology for synthesizing the results of several independent studies. Thus, an evidence-based review would provide more practical and reliable information to quantify this question for clinicians.

Materials and methods

Information sources and search strategy

A literature search was conducted in MEDLINE through PubMed databases, the Cochrane Center Library, the Web of Science, and the Wiley Online database. The following search terms were used in combination: “self-etching” or “self-adhesive”; “Class V” or “non carious cervical lesion” or “NCCL” or “cervical lesion”; “enamel etching or beveling or selective etching”. Articles published up to August 20, 2013, were reviewed and the language was restricted to English.

Inclusion and exclusion criteria

The full texts of the retrieved articles were identified and reviewed independently by two reviewers (W.Q. and L.L.), based on the inclusion and exclusion criteria (Table 1). These searches resulted in 135 primary citations matching the search terms after removing duplicates; 127 articles from the analysis were excluded for reasons such as in vitro study, primary teeth involved, or improper duration periods. Finally, eight studies were included for review (Fig. 1).
Data extraction and quality assessment

The clinical effectiveness was assessed in terms of restoration retention, the prevalence of marginal defects and marginal discoloration. The data collection included the name of the first author, publication date, number of cases, number of controls, follow-up length, rate of losses, and clinical outcomes of the three parameters mentioned previously. The qualitative assessment of the selected studies was performed using the Cochrane Collaboration’s tool for assessing the risk of bias. According to the included items, the identified articles were classified into the following criteria.

**Inclusion criteria**
1. Patients are at least 18 years of age with an acceptable oral hygiene level.
2. Participants present with noncarious cervical lesions (NCCLs) to be restored on vital teeth without mobility.
3. All NCCLs had cervical margins in dentin and incisal margins in enamel.
4. Prospective clinical trial focuses on self-etching technique in NCCLs with a minimal duration of 2 years.
5. Studies included outcome parameters, such as restoration retention, marginal defects, and marginal discoloration.
6. Articles had to report operative procedures including beveling and selective etching of enamel.

**Exclusion criteria**
1. Nonvital teeth.
2. Symptoms of pulpitis, such as spontaneous pain.
3. Abutment teeth for fixed or removable prostheses.
4. Excessive clenching, heavy bruxism, or a traumatic occlusion.
5. Allergy to materials used in studies.
6. Compromised medical history, psychological disease, or neurological disease.
7. Pregnancy or breast-feeding.

*Figure 1* Flow chart of systematic review process.

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*Table 1* Inclusion and exclusion criteria used in analysis.

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464 of records identified from database search

2 of records identified from Unpublished or undergoing research

135 of records after duplicates removed

121 of records excluded for reasons:
- 77 in vitro study or review
- 10 inlay, laser or bleaching
- 32 related to composite and adhesive agents
- 2 unrelated to self-etching adhesive

14 of records screened

6 of articles excluded for reasons:
- 3 duration period<2years
- 2 primary teeth involved
- 1 absence of adequate outcome parameters

8 of records full-text articles assessed for eligibility included in meta-analysis
categories to summarize their validity: low risk of bias, unclear risk of bias, and high risk of bias. Differences in the interpreted data were resolved by discussion between the reviewers to obtain a consensus. Otherwise, a third reviewer (Z.-M.L.) was consulted until an agreement was reached.

Data synthesis and meta-analysis methodology

Because the study results might have been presented for several periods of follow up (at 2 year, 3 years, 5 years, and 8 years), it was necessary to select a single time point and to integrate only the data at these times for the trials in which they were presented. It was also necessary to conduct a subgroup analysis to evaluate each clinical parameter according to the observation time. All restorations were clinically evaluated at each observation in the individual trials, according to modified USPHS/Ryge criteria for restoration retention, marginal defects, and marginal discoloration. Dichotomized data were collected, and a meta-analysis was performed using the Mantel–Haenszel method to obtain a pooled estimate of the overall risk ratios (RRs) with 95% confidence interval. Between-studies heterogeneity was assessed by processing the Q statistic. In the presence of substantial heterogeneity (P ≥ 0.1, $I^2 > 50\%$), a random-effect model was applied to evaluate the data, and sensitivity analysis was conducted to determine whether excluding one or more studies would reduce the heterogeneity or not. To explore for statistical heterogeneity, the sources of any possible variables, in terms of differences in clinical conditions or in methodological or assessment methods, were considered. The statistical analysis was conducted using RevMan software, version 5.0, provided by the Cochrane Collaboration.

Results

Data summary and study assessment

Among the eight clinical trials reviewed, the included items varied according to the number of involved teeth (37–132), the duration of follow up (2–8 years), and the recall rate (75–100%; Table 2). It is worth noting that four clinical reports were a series of long-term perspective trials, based on the same populations of participants and the same operative procedures at each observation time (t = 2 years, 3 years, 5 years, and 8 years), which were claimed by the authors with clear statements. Thus, we integrated the available data only after removing duplicate information. Most of the included articles, except for one, fulfilled the full-acceptance ADA guidelines for the rate of restoration loss, which was lower than 10% after an observation period of 18 months. The greatest decrease in retention rate was recorded in the nonselective etching group in the study by Van Meerbeek et al. Regarding clinical investigations in accordance with the Cochrane Collaboration’s tool for assessing the risk of bias, all eight studies were described as randomized, but none of them were double blinded. However, blinding the operator to the intervention used was not possible. Furthermore, the outcome evaluators were double blinded to the adhesive protocol used in any given restoration treatment. Two articles were judged to have a high risk of attrition bias because their follow-up loss rates were greater than 20% (Table 3).

Exploration of study heterogeneity and meta-analysis

The outcomes of the identified studies were divided into three analysis units based on the types of clinical outcome parameters, in terms of restoration retention, the prevalence of marginal defects, and marginal discoloration. Further subgroup analysis for 2- and 5-year follow up was performed within each group. For restoration retention, the included studies were heterogeneous ($\chi^2 = 262.70, df = 3, P < 0.00001, I^2 = 99\%$) at 2-year follow up. Thus, a random-effect model was created for data estimation (Fig. 2). In the forest plots, the black diamonds overlapped with the equivalence lines, and the overall RR value showed that $P = 0.21$, indicating that the differences between the selective etching and nonselective etching groups were not statistically significant. In addition, when each study was deleted in turn from the meta-analysis, we identified one article with contrasting results. This study was excluded, and the remaining articles were found to be homogeneous ($\chi^2 = 0.75, df = 2, P = 0.60, I^2 = 0\%$). Then, a fixed-effect model was used, and a similar conclusion was obtained for the overall effect, with $P = 0.44$ (Fig. 3). Although one heterogeneous study was excluded, it did not unduly influence the overall estimate. For the estimation of marginal defects and marginal discoloration, homogeneity existed among the included studies. Thus, a fixed-effect model was applied to evaluate the overall RR value. When the available data of two articles at 5-year follow up were also summarized, the prevalence of marginal defects in the nonselective etching group was significantly greater than that in the selective etching group ($P = 0.0011$; Fig. 4). The measurement selections for clinical outcomes and the analysis procedures were consistent with previous descriptions. Finally, the prevalence of marginal discoloration in the nonselective etching group was significantly greater than that in the selective etching group ($P = 0.008$; Fig. 5).

Discussion

In these identified articles, the study by Peumans et al included the results of 8-year follow up, and it was not included in meta-analysis, although the outcomes were discussed. Long-term clinical trials were the ultimate tests for evaluating the durability of adhesive restorations; however, one study showed a relatively high follow-up loss rate of 24% after 8 years. The explanation for some of the patients not being able to be contacted was that it was an older patient population (more than 50% of the patients were older than 60 years at baseline). The risk that these older patients fell ill (2 patients) or died (2 patients) within 8 years was high. Regarding the outcomes of this study, the overall retention rate was 97% after 8 years. The clinical performance with selective etching had only significantly positive effects on the marginal integrity of restorations after 8 years of clinical function.
## Table 2  Comparison of eight studies included in meta-analysis.

<table>
<thead>
<tr>
<th>Authors/year/ref</th>
<th>Teeth enrolled</th>
<th>Group Recall rate</th>
<th>6 mo</th>
<th>1 y</th>
<th>2 y</th>
<th>3 y</th>
<th>5 y</th>
<th>8 y</th>
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<td>R (n/N)</td>
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<td>MC (n/N)</td>
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<td>MC (n/N)</td>
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<td>Kubo et al (2006)</td>
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<td>100% a</td>
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<td>Peumans et al (2005)</td>
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<td>Peumans et al (2007)</td>
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<td>Fron et al (2011)</td>
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<td>Van Meerbeek et al (1995)</td>
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<td>72/60</td>
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<td>98% i</td>
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**Notes:**
- MC = marginal discoloration; MD = marginal defects; n/N = number of cases over total number of participants; R = retention.
- a Teeth with selective enamel etching.
- b Teeth with nonselective etching.
The heterogeneity shown in Fig. 2 disappeared after the exclusion of one study with a different outcome. Although one heterogeneous study was excluded, the conclusion was "stable", which indicated that the selective enamel etching approach resulted in no significant improvement in retention compared with the nonselective etching group. It could be helpful to distinguish the source of heterogeneity. However, if an obvious reason for the outlying result was apparent, the study might be removed with more confidence. The study that was excluded from the meta-analysis (but not deleted from the systematic review) investigated the clinical performance of early SE adhesives (Tenure and Tripton), and it had distinct differences from other studies. Considering that the Tenure and Tripton SE adhesive systems resulted in high retention losses (loss rates of 30% for Tenure and 55% for Tripton), assessing the residual restorations in place for marginal defects and marginal discoloration might have resulted in a high risk of bias due to the absence of adequate information. An extended discussion appeared to address the high failure rates that were reported in this clinical investigation. Excellent marginal integrity was only recorded for 10% for Tenure and 8% for Tripton, respectively, in restorations without any intentional enamel involvement. For Tenure, the less reliable retention might have resulted from insufficient wetting and incomplete resin penetration of the demineralized surface of the dentin layer. In addition, Tenure was observed to develop acid-resistant crystals of calcium oxalate, which might chemically prevent not only an appropriate depth of external dentin demineralization, but also sufficient penetration of resin into the dentin structure. Regarding Tripton, the loosely bounded layer of smear debris remained intact, and the tubule orifices were obstructed with globular particles without a hybrid layer formation. The slight separation of the interface between the dentin and the restoration resin, as detected by scanning electron microscopic (SEM) images, indicated poor wetting and the weak bonding capacity of Tripton. Regarding the restorative materials used for Tripton adhesion, Opalux (GC) is a fine, compact-filled composite resin with particle sizes larger than 3 \( \mu m \) and with a relatively high module of elasticity. It is worth noting that a correlation was reported by Kemp-Scholte between the higher modulus of elasticity of the resin composite and the greater occurrence of cervical marginal gaps. Nevertheless, when both SE adhesive approaches were used, in combination

<table>
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<th>Authors/year/refs</th>
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<th>Performance bias</th>
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<th>Attrition bias</th>
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Figure 2 Forest plot of comparison: the selective etching group versus the nonselective etching group at 2- and 5-year follow-up analysis. "Events" stands for retention \( (P = 0.21) \). CI = confidence interval; M-H = Mantel–Haenszel.
with previous enamel beveling and selective etching, the clinical outcomes were substantially improved.24

Retention rate was the most obvious sign and the most reliable diagnostic evaluation criterion, with few variations of failures in NCCL restorations. In the present review, at follow ups of up to 2 years and 5 years, the clinical performance of the two groups was equal, and 100% retention rates were recorded in most of the clinical trials for both groups. Consistently, the results of laboratory tests suggested that enamel beveling might reduce the stresses generated by polymerization contraction and by thermal and flexural load cycling. In addition, the enamel beveling produced an oblique section of enamel rods and thus might enhance the bonding strength.28 One possible explanation for the absence of significantly different retention results when using adhesives with selective enamel etching was sufficient acidity of the SE adhesive (pH $\geq 2.3$) to achieve reliable bonding to enamel, although it could be considered a mild SE adhesive because its pH was greater than 2. The SE adhesives interact with dentin rather superficially, producing a hybrid layer of approximately 1 mm in depth. This simultaneous demineralization and infiltration of dentin result in a shallow, but uniform and thus stable, resin-infiltrated dentin layer.29 Besides, the additional chemical bonding efficacy of the functional monomer, 10-methacryloxydecyl dihydrogen phosphate (10-MDP), with tooth minerals not only contributes to the adhesive potential to dentin but also to the enamel, which consists of nearly entirely of a mineral substance that chemically reacts with 10-MDP.

Figure 3  Forest plot of comparison after deletion of one heterogeneous study: the selective etching group versus the nonselective etching group at 2- and 5-year follow-up analysis. “Events” stands for retention ($P = 0.44$). CI = confidence interval; $M-H = Mantel–Haenszel$.

Figure 4  Forest plot of comparison: the selective etching group versus the nonselective etching group at 2- and 5-year follow-up analysis. “Events” stands for marginal defects ($P = 0.0001$). CI = confidence interval; $M-H = Mantel–Haenszel$. 
Compared with the retention rate, marginal defects and discoloration were outcomes that showed greater variability between individual evaluators. It was emphasized that if marginal defects were small, they could hardly be spotted by the naked eye and could only be examined by moving a sharp probe with light pressure across the restoration-and-tooth margin. Indeed, these small shortcomings only had slight effects on the clinical effectiveness of the restorations because they could be resolved by refinishing and repolishing. The current review found that restorations created without previous etching showed more marginal defects and discoloration. The etching patterns of SE adhesives were poorer, compared with those resulting from phosphoric acid etching. The frequency of marginal defects increased with time, resulting in an increase in the prevalence of slight marginal discoloration. In the study by Kubo et al, the SEM images showed minor marginal defects associated with a slight excess of material covering the enamel or the resin composite restoration, and these defects increased with time with both adhesive techniques. Indeed, it was proved that degradation of the integrity of margins was correlated with the occurrence of marginal discoloration, and it took a few years for marginal defects to be manifested clearly as marginal staining. The effectiveness of enamel bonding decreased with time, as demonstrated by in vitro studies after durability testing. In the current review, the number of marginal defects and discoloration were significantly less often in the selective etching group at 2- and 5-year follow up.

The longevity of resin composite restorations was dependent on many factors, including operator skill, restorative materials, and occlusal stress. With respect to operator factors, Giachetti et al reported that total-etching and SE adhesives were sensitive to operator skill in obtaining a reliable seal with the enamel. Both adhesives demonstrated little sensitivity to operator skill on the dentin. Accordingly, most articles claimed that experienced dentists were involved in their studies. With regard to the influences of outcome evaluators, all of the included articles stated that the evaluators were blinded to the adhesive protocol used in any given restoration. Although there might have been an evaluation bias, it would rather be a systematic bias because the evaluators were "blinded" to adhesive techniques allocation during follow ups. Regarding resin composites, the use of a nano-filler resin (CLEARFIL AP-X, Kuraray Co., Ltd, Tokyo, Japan) might have had positive effects on longevity. The nano-filler composite (20 nm, according to the information provided by the manufacturer) resulted in a thicker adhesive layer and a more flexible interface, which were believed to decrease the interfacial tensile stress between the shrinking composite restorations and the rigid dentin structure. It seemed that such a flexible composite resin might also help to relieve other stress factors (such as occlusal load), which might have contributed to the excellent clinical performance of the restorations over time. The two clinically unacceptable restorations in the article by Peumans et al were placed on the mandibular molars. The restoration retention revealed poor clinical outcomes in cases of heavy occlusal load, such as bruxism and malocclusion. For operative procedures, although previous beveling of the enamel and selective phosphoric acid etching were not correlated with better clinical effectiveness of restoration retention, intentional enamel involvement improved marginal integrity, with fewer marginal defects. Regarding resin composite, the clinical performance improved as the modulus of elasticity of the resin composites decreased. With a high ratio of bonded surface to unbonded surface, the resin composite materials with maximum flowability are recommended to restore NCCL. With regard to the influence of patient factors on restoration replacements, secondary caries was the most prevalent reason for failure of restorations, indicating that good oral hygiene enhanced restoration longevity. Excessive and heavy occlusal function had been associated with reduced longevity of restoration.
exclusion criteria for compromised medical history, heavy bruxism, or carries sensitivity were clarified in most of the involved studies.17–23 With regard to the information on patient’s age, five articles17,18,21–23 had clear statements. Furthermore, it had to be considered in clinic practice that an adhesive applied with higher degrees of dentin sclerosis in older patients had poor clinical performance.39 Smoking was reported to exert a positive effect on the presence of marginal discoloration.40

In conclusion, based on the results of this analysis, fewer defects at the restoration margins were recorded following the selective enamel etching approach. The restoration retention and marginal discoloration outcomes based on previous etching of the enamel had no significant differences compared with the nonselective etching group. These conclusions were based on data from observation durations of up to 5 years. Thus, long-term follow ups and large-scale prospective clinical trials should be expected to evaluate the possible benefits of previous phosphoric acid enamel etching in NCCL restorations.

Conflicts of interest

The authors declare that there are no conflicts of interest that could influence their work.

References


