# Repair or Observation of Resin Margin Defects: Clinical Trial After Five Years

JB Dennison • P Yaman • DJ Fasbinder • AA Herrero

### Clinical Relevance

Discoloration in composite restoration margins does not indicate the presence or predict the development of recurrent caries over five years in a low- to moderate-risk population. Discoloration at composite resin margins can be repaired to improve esthetics, but it is likely to return at a decreasing rate over time.

## SUMMARY

**Objective: To assess the effectiveness of repair/ resealing of stained composite margins as an alternative to controlled observation without treatment in a randomized clinical trial after five years.**

**Methods and Materials: Each patient recruited had from one to three composite restorations with visible margin discoloration. Initially, the characteristics of each defect were recorded with direct vision through a surgical micro-** scope at 20× magnification. Clinical evaluation was done by two independent examiners using modified USPHS criteria for color, margin discoloration, and margin adaptation. Each restoration was then randomly assigned to a control or treatment group. Control restorations were observed yearly for the presence of recurrent caries; treatment restorations were resealed by exposing the margin with a ¼ round bur, removing all interfacial stain, acid etching, placing an adhesive bonding agent, and a flowable composite to restore margin integrity. There were 152 patients recruited, with 360 restorations (180 control and 180 treatment).

**Results: At five years, 104 patients were recalled (68%) with 271 restorations (76%): 136 untreated control and 135 resealed restorations. At that time, 61 restorations had been lost or replaced for nonrelated reasons. Clinical evaluation of the remaining 210 restorations determined penetrating discoloration (control = 81%, resealed = 46%) and margin crevice formation (control = 21%, resealed = 11%). Recurrent caries was diagnosed cumulatively in only six control and five treatment restorations (<5%). Microscopically, 49 control**

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restorations (49%) and 36 resealed restorations (33%) had crevice formation. Discoloration was distributed as follows: 9% vs 47% with no discoloration, 30% vs 33% in the composite, 49% vs 18% in the interface, and 12% vs 2% in tooth structure.

**Conclusions:** Resealing of restorations with margin discoloration reduced the occurrence of penetrating stain from 81% in controls to 46% in resealed margins and crevicing from 21% to 11% after five years. Both controlled observation and resealing of margins resulted in a similar very low incidence (<6%) of recurrent caries.

## INTRODUCTION

Margin discoloration has generally been considered a sign of early failure in composite resin restorations and is often used as a criterion for restoration replacement.[1] The assumption is that discoloration is associated with debonding and fluid penetration into the interfacial space.[2,3] The ingress of cariogenic fluid associated with plaque retention has been specified as a potential cause of recurrent caries.[4] There is little clinical evidence in the recent literature to support this cause-and-effect relationship *in vivo*.[5]

The seal of a cavity margin has been investigated for many years, especially with the development of newer bonding agents and adhesive materials. Much of the published research has been based on *in vitro* microleakage studies, which involve assessing the penetration of tracer solutions into the interface. After a restored extracted tooth is exposed to a tracer solution, usually in conjunction with an external stimulus, it is sectioned through at least one margin interface. Dark-colored dyes, such as methylene blue[6,7] and basic fuchsin,[8,9] as well as silver nitrate,[9,10] are tracers that can readily be identified on tooth cross sections. The degree of penetration along the interface is assessed using either a rating scale[9-12] or measuring software.[13,14] To simulate clinical performance, external stimuli are often applied, such as thermal[8,10,15,16] and/or mechanical cycling.[17,18]

There have been attempts to correlate these *in vitro* tests with clinical performance, but they have been largely unsuccessful at establishing a direct relationship.[19,20] It is possible that a relationship could be established if studies were restricted to a highly caries active population and margin discoloration was considered as one contributing factor.

However, in such a population, there are also many factors that contribute to caries development, such as genetics, diet, oral hygiene compliance, education, socioeconomics, and chronic medical conditions that require medication.

This lack of cause-and-effect association has led to the concept of restoration repair as an alternative treatment to restoration replacement.[21] A number of studies have documented short-term clinical success with restoration repair procedures, which is less invasive, more conservative of adjacent tooth structure, and less costly to provide.[22-24] Margin debonding and discoloration usually occur in a localized area of the exposed margin and are often associated with a small defect or discontinuity at the interface, frequently created through wear, occlusal forces, or inadequate initial adaptation of the restorative material. With adequate access and isolation, margin repair should be a treatment of choice, especially in moderate- to low-risk populations. It has also been shown by Hamilton and others[25] in a randomized trial that the progression of diagnosed pit and fissure incipient caries can be very slow and that observation may be another viable alternative.

The purpose of this study was to morphologically characterize the defective margin area associated with discoloration in teeth where there is no evidence of active recurrent caries and to conduct a randomized clinical trial to assess the effectiveness of resealing the margin with a flowable composite resin.

### Hypothesis and Specific Aims

The null hypothesis for this study was that the incidence of recurrent caries associated with composite restorations that have margin discoloration is equivalent after five years of observation to those occurring in restorations with similar defects that have been resealed. The alternative hypothesis was that the incidence of recurrent caries associated with composite restorations that have margin discoloration is significantly reduced over five years by resealing the involved margin.

The specific aims to be accomplished by the study were 1) to characterize the morphology of margin discoloration clinically using a surgical microscope, 2) to determine the incidence of recurrent caries associated with margin discoloration over five years, 3) to describe the clinical changes in restoration margins with discoloration over a five-year period, and 4) to assess the efficacy of a resealing procedure as an alternative to extended clinical observation.
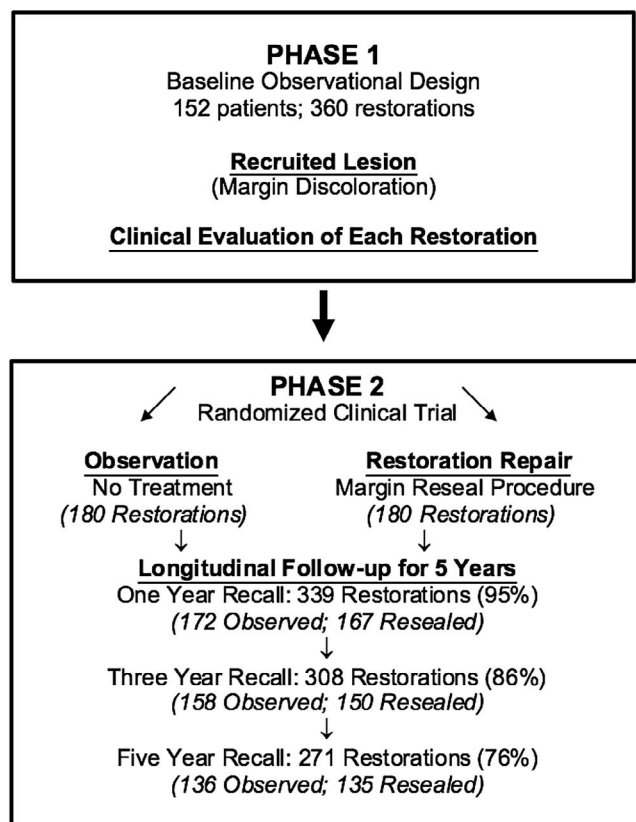
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┌─────────────────────────────────────────────┐
│                   PHASE 1                      │
│          Baseline Observational Design         │
│          152 patients; 360 restorations        │
│                                                │
│               Recruited Lesion                 │
│             (Margin Discoloration)             │
│                                                │
│      Clinical Evaluation of Each Restoration   │
└─────────────────────────────────────────────┘
                        ↓
┌─────────────────────────────────────────────┐
│           ↙        PHASE 2        ↘            │
│            Randomized Clinical Trial           │
│                                                │
│   Observation          Restoration Repair      │
│   No Treatment        Margin Reseal Procedure   │
│  (180 Restorations)     (180 Restorations)      │
│         ↓                      ↓                │
│       Longitudinal Follow-up for 5 Years       │
│     One Year Recall: 339 Restorations (95%)    │
│        (172 Observed; 167 Resealed)            │
│                      ↓                          │
│     Three Year Recall: 308 Restorations (86%)  │
│        (158 Observed; 150 Resealed)            │
│                      ↓                          │
│     Five Year Recall: 271 Restorations (76%)   │
│        (136 Observed; 135 Resealed)            │
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Figure 1.  *Study design and patient flow through the study period.*

## METHODS AND MATERIALS

The first phase of the study was a single-variable observational design, and the second phase was a randomized clinical trial (Figure 1). A total of 152 patients were recruited from the clinics at the School of Dentistry as they appeared for routine recall and/or restorative treatment. The baseline clinical and morphological data collected at the initiation of the study included 360 restorations that met the specified inclusion criteria. The study protocol and consent form were approved by the Health Sciences Institutional Review Board at the university. Each patient who participated was given a full description of the study and voluntarily signed a patient consent form.

The inclusion criteria required that each patient have at least one and no more than three existing composite restorations with visual evidence of discoloration on an accessible margin but no diagnosis of recurrent caries. The criteria for recurrent caries were one of the following: 1) a margin crevice with tactile softness to an explorer, 2) white surface demineralization with cavitation, or 3) undermining opacity in enamel or color change within dentin. All

margins had to be located at the gingival crest or above; the patient had to be able to perform normal hygiene procedures and be available for five yearly recalls.

## Evaluation Procedures

For each restored tooth that was enrolled in the study with a defective margin, the following clinical measurements and evaluations were made at the baseline appointment:

- The observed color of the defect was recorded, and the length and width of the discolored area was measured to the nearest 0.5 mm with a Goldman-Fox periodontal probe (Hu-Friedy Mfg Co, Chicago, IL, USA) marked in 1-mm increments.
- Each restoration was evaluated independently by two trained examiners using modified USPHS criteria[26,27] for color match, margin discoloration, margin adaptation, and recurrent caries, the primary outcome for the study (Table 1).
- A microscopic evaluation of margin defects was made at 20× magnification using a surgical microscope (Urban, Global Surgical Corp, St Louis, MO, USA). A visual description of the location of the discoloration within the margin and the microstructure of the defective margin were recorded, as viewed directly through the microscope and evaluated according to the criteria in Table 2.

## Treatment Procedures

After the baseline measurements were completed, each tooth was then randomly assigned to either a control group or a reseal treatment group for study in the longitudinal clinical trial. Restorations in the control group received routine prophylaxis and were observed at a yearly recall using the same protocol. The primary outcome measure was the development of recurrent caries in the area of the defect.

Restorations in the treatment group were repaired or resealed using a technique similar to that of a sealant on enamel pits and fissures. The tooth was cleaned using a rubber cup and a pumice slurry. Local anesthesia was not administered for this procedure, and cotton roll isolation with high-volume evacuation was used to maintain a dry field. The discolored margin was exposed with a ¼ or ½ round bur, removing all stain from the interface and exposing sound adjacent tooth structure on one side of the margin. All of the marginal interface was then etched with 37% phosphoric acid for 30 seconds and

| Table 1: | *Modified Ryge Criteria for Evaluation of Tooth-Colored Restorations* | |
|---|---|---|
| **Criteria** | | **Rating** |
| Color match of restoration | | |
| Color of reseal is not readily visible | | alpha |
| Color of reseal is readily visible but acceptable | | bravo |
| Color of reseal is an obvious mismatch | | charlie |
| Margin discoloration (stain) | | |
| Margin discoloration is not evident | | alpha-1 |
| Margin discoloration is evident on <50% of exposed margin | | alpha-2 |
| Margin discoloration is evident on >50% of exposed margin | | alpha-3 |
| Margin discoloration is penetrating along <50% of exposed margin | | bravo-1 |
| Margin discoloration is penetrating along >50% of exposed margin | | bravo-2 |
| Margin adaptation | | |
| Margin barely detectable when explorer is run in either direction | | alpha-1 |
| Margin detectable when explorer is run in either direction | | alpha-2 |
| Visible and detectable crevice formation | | |
| Explorer penetrates along <50% of exposed margin | | bravo-1 |
| Explorer penetrates along >50% of exposed margin | | bravo-2 |
| Visible crevice formation with exposure of underlying dentin | | charlie |
| Recurrent caries | | |
| Not present | | alpha |
| Present | | bravo |

| Table 2: | *Criteria Used to Describe the Magnified Margins* |
|---|---|
| **Contour at Interface** | **Location of Discoloration** |
| Ideal contour | Interface space |
| Underfilled | Composite material |
| Overlap | Adjacent tooth structure |
| Shallow crevice | |
| Deep crevice | |

95% at year 1 to 76% at year 5 based on the number of restorations evaluated (Figure 1). Data are available for all five yearly recall periods, but only years 1, 3, and 5 are reported in the following tables to save space and yet demonstrate the important trends. The patients were older and at one time had a higher risk for caries based on their existing restorations. At the time the study was started, most patients were in a managed maintenance setting, but some were also being treated for a few new lesions.

## Morphologic Characterization (Clinical Microscope at 20×)

Complete baseline, three-year, and five-year data for stain location at the margin interface, as viewed directly through a surgical microscope, are shown in Table 3. All evaluations were made by direct vision through the microscope eyepiece. Randomization of the baseline assignments was very effective in producing almost identical location distributions in both treatment and control groups. At one year, 153 controls continued to exhibit staining in one location (92.7%), while the resealed group was skewed toward "no discoloration" (107 restorations, 65.6%). Similar patterns were demonstrated in the resealed group at both three years (69 restorations, 50.4%) and five years (52 restorations, 47.3%). At five years, the stain was more in the composite than in the interface (32.7% vs 18.2%) for the resealed group, while the reverse was true of the control group (30% vs 49%). Only 12 (12%) of the untreated control restorations and two (1.8%) of the resealed restorations evaluated showed evidence of stain in the tooth structure, which may explain the lower incidence of recurrent caries over time in these defective margins. After five years, 79% of the control restorations and 50.9% of the resealed restorations had stain accumulation in either the interface or in the composite, which did not appear to have a demineralizing effect on adjacent tooth structure.

For margin contour, as evaluated microscopically (Table 4), 33% of the restorations in each group had

rinsed thoroughly for 15 seconds. A dentin bonding agent (Optibond Solo Plus, Kerr Mfg Co, Orange, CA, USA) was then applied in a thin coat and photocured for 10 seconds using a standard halogen light (650 mwatts/cm$^2$ intensity). This was followed by placing a flowable composite resin (Revolution, Kerr Mfg Co) over the area to restore restoration contour and margin integrity. The sealed margin was then reevaluated posttreatment as well as at 6 months and at yearly recalls for the five-year period.

## RESULTS

### Study Population

A total of 152 patients were recruited with 360 teeth that met the inclusion criteria; 180 were randomized to the control group for observation and evaluation and 180 to receive the resealing treatment. Recall rates steadily decreased over the five years, from

| Table 3: Microscopic Stain Location Within the Restoration Margins at Each Recall Period (Number of Restorations)[a] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Baseline | | One Year | | Three Year | | Five Year | |
| | Ct | Tx | Ct | Tx | Ct | Tx | Ct | Tx |
| Restoration evaluated | 180 | 180 | 165 | 163 | 132 | 137 | 100 | 110 |
| Interface | 97 | 90 | 77 | 18 | 74 | 28 | 49 | 20 |
| Composite | 65 | 64 | 60 | 30 | 38 | 33 | 30 | 36 |
| Tooth | 18 | 26 | 16 | 8 | 13 | 7 | 12 | 2 |
| No Stain | 0 | 0 | 12 | 107 | 7 | 69 | 9 | 52 |
| Replaced, lost | 0 | 0 | 7 | 4 | 26 | 13 | 36 | 25 |
| Not available | — | — | 8 | 10 | 22 | 27 | 44 | 42 |

*Abbreviations: Ct, untreated control; Tx, resealed treatment.*
[a] *At five years, resealed restorations had a significantly greater number without stain than controls. Chi-square, p<0.001.*

overlapped resin margins at baseline, while another 50% to 53% had crevices at the margin interfaces. The general distribution remained the same for the control group (33% overlap; 49% crevice) after one year; however, 75 (46%) of the resealed restorations evaluated had continuous margins and only 22 (13%) exhibited crevices. At three years and even more so at five years, margin defects were more evident and the distribution of the defects in treated teeth approached those of the untreated controls (31% vs 40% overlap; 49% vs 33% crevices at five years). Shallow crevices did not appear to progress to deeper crevices over time and were similar in both treated (23%) and untreated (37%) groups at five years. Significant patient loss occurred with time, as the population was more focused in the elderly. During the five years, there were 36 teeth in the control group, in which restorations were lost to recall; seven were replaced with crowns, bridges, or veneers; eight were debonded or missing; 15 were replaced inadvertently in the predoctoral clinic; and six were replaced due to caries. For the treatment group, 25 restorations were lost to recall; five were replaced with crowns, bridges, or veneers; 10 were

debonded; five were replaced inadvertently; and five were restored due to caries. These were reported at various yearly intervals as patients appeared for recall appointments.

## Clinical Evaluation

Clinical evaluations were made for each restoration using the modified Ryge criteria at baseline, post-treatment, and at each yearly recall.[26] The four major characteristics evaluated were color match, margin discoloration, margin adaptation, and recurrent caries. The data for color match did not reveal any noticeable change in color over the five years, and the resealed areas were not readily visible from the original restoration by color change.

For margin discoloration at baseline (Table 5), approximately 77% to 82% in each group showed penetrating stain. About one-third of these restorations showed penetrating stain along greater than 50% of the visible margin on the exposed surface. Since discoloration was a criterion for inclusion, there were no restorations without stain, and 23% showed only surface stain at the interface. At posttreatment (TxP), 98% of restorations were rated

| Table 4: Microscopic Contour of the Restoration Margin at Each Recall Period (Number of Restorations)[a] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Baseline | | One Year | | Three Year | | Five Year | |
| | Ct | Tx | Ct | Tx | Ct | Tx | Ct | Tx |
| Restoration evaluated | 180 | 180 | 165 | 163 | 132 | 137 | 100 | 110 |
| Ideal | 3 | 7 | 10 | 75 | 12 | 44 | 11 | 25 |
| Under fill | 22 | 25 | 19 | 10 | 14 | 12 | 9 | 5 |
| Overlap | 60 | 58 | 55 | 56 | 38 | 47 | 31 | 44 |
| Shallow crevice | 63 | 61 | 59 | 16 | 46 | 18 | 37 | 25 |
| Deep crevice | 32 | 29 | 22 | 6 | 22 | 16 | 12 | 11 |
| Replaced, lost | — | — | 7 | 4 | 26 | 13 | 36 | 25 |
| Not available | — | — | 8 | 10 | 22 | 27 | 44 | 42 |

*Abbreviations: Ct, untreated control; Tx, resealed treatment.*
[a] *At five years, resealed restorations had a significantly greater number without margin crevices than controls. Chi-square, p=0.016.*

| Table 5: | Clinical Evaluation of Margin Discoloration at Each Recall Period (Number of Restorations)[a] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Baseline** | | | **One Year** | | **Three Year** | | **Five Year** | |
| | **Ct** | **Tx** | **TxP** | **Ct** | **Tx** | **Ct** | **Tx** | **Ct** | **Tx** |
| Restoration evaluated | 180 | 180 | 177 | 165 | 163 | 132 | 137 | 100 | 110 |
| No discoloration | 0 | 2 | 160 | 12 | 116 | 11 | 79 | 10 | 54 |
| Surface stain | 42 | 41 | 15 | 12 | 17 | 8 | 9 | 9 | 5 |
| Penetrating <50% | 94 | 87 | 2 | 90 | 27 | 69 | 40 | 47 | 41 |
| Penetrating >50% | 44 | 50 | 0 | 51 | 3 | 44 | 9 | 34 | 10 |
| Replaced, lost | — | — | 3 | 7 | 4 | 26 | 13 | 36 | 25 |
| Not available | — | — | | 8 | 10 | 22 | 27 | 44 | 42 |

*Abbreviations: Ct, untreated control; Tx, resealed treatment; TxP, posttreatment.*
[a] *At five years, resealed restorations had a significantly greater number without penetrating margin discoloration than controls. Chi-square, p<0.001.*

without discoloration or with a slight surface translucency. For the restorations evaluated after one year, 116 restorations (71%) in the treatment group showed no evidence of discoloration, as opposed to 12 restorations (7%) in the control group. At each recall period, there was still a significantly greater number without discoloration in the treatment group: 57% vs 8% at three years and 49% vs 10% after five years. Figure 2 shows the contrast between the rates at each yearly recall and that the rate of recurrence increases steadily with time. At some future time, it can be expected that the margin discoloration in both groups will be similar if the trends continue. Figure 3 shows a sequence of photographs with recurring margin discoloration after five years.

For margin adaptation (Table 6), the distribution of defects was also similar for the treatment and control groups at baseline. Approximately 48% of each group had a one-way margin catch, and 41% to 47% had a detectable crevice. Less than 11% of these margins had crevices that extended along more than 50% of the exposed margin. At posttreatment examination (TxP), 160 (90%) of the resealed margins were rated as barely detectable, 17 (9%) as readily detectable, and three were dislodged during the treatment. There were no margin crevices after retreatment. After one year, 80 resealed restorations (49%) were barely detectable; 72 (44%) had a definite one-way catch and only 11 (7%) had a localized margin crevice. In comparison with the control group, the effective reduction in margin crevices with resealing was 26% after one year. Five years after retreatment, 30 margins (27%) were barely detectable; 68 (62%) were readily detectable and 12 (11%) showed crevicing. In contrast, the untreated restorations had 68% with readily detectable margins and 21% with crevices.

The primary outcome of the study was to determine the failure rate of repaired restorations due to recurrent caries. The results in Table 7 show that the cumulative incidence of recurrent caries over five years was only 4.4% without retreatment and 3.7% with retreatment. In both groups, only 7% to 8% of the restorations were totally debonded or lost. Using a chi-square test at $p<0.05$, these losses were not significantly different with or without the resealing treatment. Figure 4 shows a baseline and five-year photograph of a typical lesion that was observed over the five yearly recalls without treatment.

## DISCUSSION

In reviewing the literature at the time the study was proposed, the anticipated incidence of recurrent caries around the discolored margin of a composite restoration was about 30%.[28,29] In recent years, there has been increasing support to repair rather than to replace composite restorations with defective margins, assuming the restoration is otherwise in satisfactory condition.[21,22] In developing a restorative treatment plan for a patient with composite restorations that have discolored margins, it is a difficult decision whether to suggest continued observation, repair, resealing, or full replacement. Many risk factors also enter into this decision, even if the diagnosis of active recurrent caries is not justified, such as age of the restoration, oral hygiene of the patient, dental restoration history, fluoride application history, and operative access to the discolored margin. Given these variables, this fully randomized clinical trial was initiated to gain evidence to support two of the treatment suggestions.

One interesting parameter which might give a suggestion as to which type of discoloration would be most likely to develop a margin lesion, given a
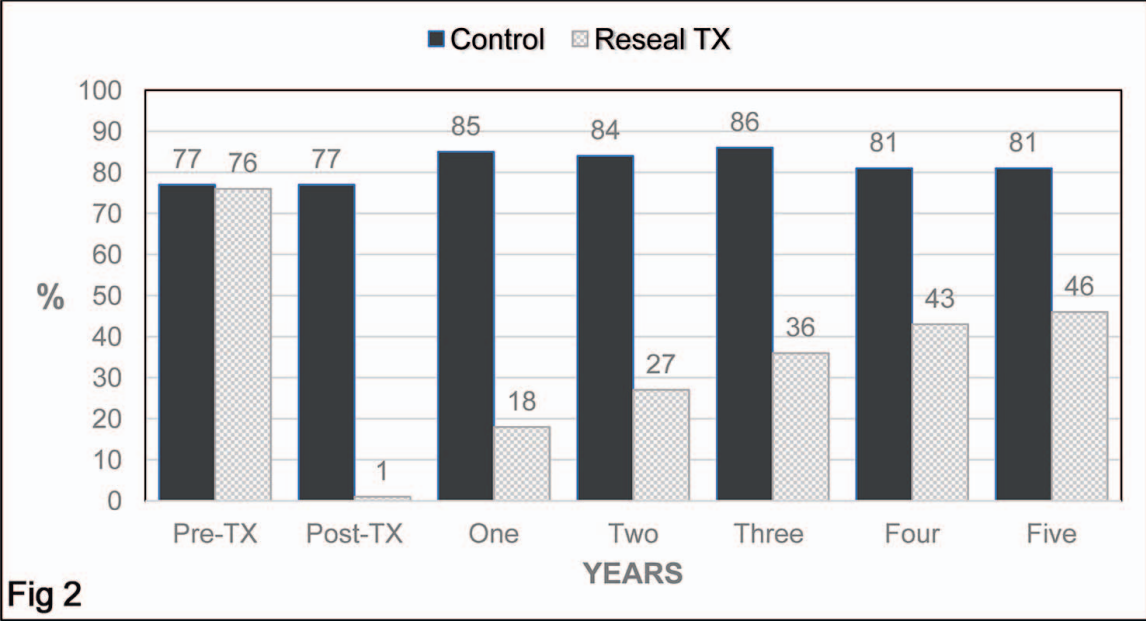
Fig 2



Fig 3 - A   B   C   D

Figure 2.   *Clinical evaluation of penetrating margin discoloration in percentage over five years.*

Figure 3.   *Resealing treatment sequence. (A): Preoperative baseline. (B): Preparation. (C): Posttreatment baseline. (D): Five years posttreatment.*

characteristic defect, is the location of the stain along the interface. During the baseline evaluation, a surgical microscope was used to evaluate the location of the stain and the margin configuration at the point of staining. Randomization of patients as they were recruited proved to equally distribute the characteristics between the treatment and control groups for all of the criteria studied (Tables 3-6). In looking at the baseline distribution, it seems likely that stain in the composite material and stain from accumulated material lodged in the interface would be less likely to develop into recurrent caries than

| Table 6: | *Clinical Evaluation of Margin Adaptation at Each Recall Period (Number of Restorations)*[a] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Baseline** | | | **One Year** | | **Three Year** | | **Five Year** | |
| | **Ct** | **Tx** | **TxP** | **Ct** | **Tx** | **Ct** | **Tx** | **Ct** | **Tx** |
| Restoration evaluated | 180 | 180 | 177 | 165 | 163 | 132 | 137 | 100 | 110 |
| Barely detectable | 20 | 11 | 160 | 24 | 80 | 22 | 55 | 11 | 30 |
| Readily detectable | 87 | 85 | 17 | 87 | 72 | 80 | 67 | 68 | 68 |
| Crevice <50% | 58 | 72 | 0 | 44 | 11 | 22 | 14 | 18 | 12 |
| Crevice >50% | 15 | 12 | 0 | 10 | 0 | 8 | 1 | 3 | 0 |
| Replaced, lost | — | — | 3 | 7 | 4 | 26 | 13 | 36 | 25 |
| Not available | — | — | | 8 | 10 | 22 | 27 | 44 | 42 |

*Abbreviations: Ct, untreated control; Tx, resealed treatment; TxP, posttreatment.*
*[a] At five years, resealed restorations had a significantly greater number without crevices than controls. Chi-square, p=0.045.*

| Table 7: *Clinical Outcomes After Five Years (Number of Restorations)*[a] | | | | |
|---|---|---|---|---|
| Treatment | Recall Period, y | Restorations Recalled (Including Replaced or Lost) | Recurrent Caries (Cumulative) | Lost Restorations (Cumulative) |
| Control (CT) | 1 | 172 (95.6%) | 0 | 2 (1.2%) |
| Reseal (TX) | 1 | 167 (94.4%) | 0 | 3 (1.8%) |
| Control (CT) | 3 | 158 (87.8%) | 5 (3.2%) | 8 (5.1%) |
| Reseal (TX) | 3 | 150 (84.7%) | 2 (1.3%) | 6 (4.0%) |
| Control (CT) | 5 | 136 (75.6%) | 6 (4.4%) | 9 (6.6%) |
| Reseal (TX) | 5 | 135 (76.3%) | 5 (3.7%) | 11 (8.1%) |

[a] At five years, there was no difference between resealed restorations and controls in the number of restorations lost (chi-square, p=0.639) or with recurrent caries (chi-square, p=0.707).

stain that has affected adjacent tooth structure. Such stain may be an indication that a wall lesion is beginning to form.[18,30-32] The sample size in this group was small (10% to 14%); however, in evaluating the 18 restorations that showed color in the tooth side of the interface, 13 were sound at five years, three had been replaced for noncarious reasons after being noncarious at two years, one did not attend any recalls, and only one became active caries at the three-year recall. Therefore, this factor was not as good a predictor for recurrent caries development as was anticipated.

Another factor that has been indicated as a contributing cause for recurrent caries is crevice formation at the interface.[29,33] It is assumed that a margin crevice creates a hidden area for bacteria to accumulate and incubate to the point of causing demineralization. This may be true, but it was a very slow process in this population. Of the 11 restorations that were diagnosed with active recurrent caries through the five years, five were diagnosed at two years, two at three years, two at four years, and two at five years. Eight of these restorations (73%) had crevices microscopically at baseline; six were in the control group and two were in the treatment group. However, that represents only 6% of the total restorations in the control group that had microscopic crevices at baseline and later developed caries during observation. Therefore, the development of a margin crevice also seems to be a relatively weak predictor of future recurrent caries.

From Table 5 and Figures 2 and 3, margin discoloration did reappear in repaired restorations over the five years of this study. The important factor is the time period curve and the extent of this recurrence interval. After five years, recurrence of the staining was still only at 46% as opposed to a consistent 80% for the untreated control restorations, an effective reduction of 35%. The incremental recurrence was 18% the first year, 9% additional at the second year, 9% at the third year, 7% at the fourth year, and 3% at the fifth-year recall. The yearly incremental recurrence may have decreased with time because of the patient characteristics of those returning for recall, the effect of increased awareness on oral hygiene, the effectiveness of the resin bond at the margin with a flowable material, or the location of the stained margin on the restoration. There was no comparison made to see if the recurrent stain was in the same location on the restoration margin or within the margin as the original one that was repaired. An assumption can also be made that the rate of recurrence diminishes over time in a population like this.

When evaluating the quality of restorations returning for recall over a long period of time, there also has to be consideration of the restorations that were lost in returning patients and those that did not return at all for recall. In the retreatment group, there were four restorations (3%) lost and 10 (6%) not available at one year, 13 (9%) lost and 27 (15%) not available at three years, and 25 (19%) lost and 42 (24%) not available after five years. It is impossible
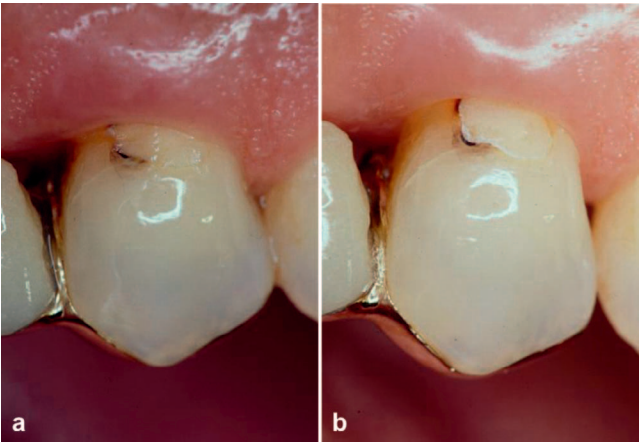


Figure 4. *Typical untreated lesion as observed at baseline (A) and after five years (B).*

to say whether the incidence of returning stain for the recalled group is representative of those unevaluated restorations or whether their incidence would have been greater.

Another variable that should be considered is the study population. No attempt was made to formally evaluate each patient's individual risk, but every patient had a restorative history with existing restorations to qualify for the study. The estimated caries risk for the group was low to moderate in most cases, applying criteria published by Fontana and Zero.[34] The patient pool at the dental clinic tends to be from a somewhat lower socioeconomic status. The water in the area is fluoridated, and the patients recruited were attending the clinic for recall maintenance or routine restorative treatment. All were educated in oral hygiene procedures and were concerned about their oral health. Had the study been conducted in a population with high caries risk, the recurrence of margin staining and the incidence of recurrent caries might have been greater. Then the resealing technique would probably have been less effective.

The incidence of recurrent caries was less than 5% for both groups over the five years, and there was not a significant difference between the two groups. This indicates that there was no improvement in restoration longevity by resealing the margins of stained restorations as opposed to continued observation over five years. This conclusion is in agreement with previous studies, which have shown a positive result from restoration repair,[33,35] but there is no documentation for a group undergoing continued observation at yearly recalls without any intervention. If resealing stained restoration margins does not improve longevity, certainly full restoration removal and replacement are contraindicated, except to improve esthetics. Based on these data, it is reasonable to conclude that staining of a composite restoration margin does not lead to the development of recurrent caries in adjacent tooth structure.

## CONCLUSIONS

Under the conditions stated for this study of discolored composite restoration margins over five years, the following conclusions can be made:

1. The incidence of recurrent caries was very low and similar for restorations with discolored margins that were either resealed or just observed over five years.
2. Neither the depth of discoloration nor the location of the stain within a restoration margin were

valid predictors of subsequent recurrent caries over the same period.
3. Penetrating margin stain was removed by resealing but returned in a significant number of restorations over the five years.
4. Noncarious discolored or defective composite margins are not a definitive indication for restorative intervention.

### Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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