# Self-Bonding Polymers as Surface Coatings of Restorative Resins to Prevent Staining

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- **Objective:** Discoloration caused by staining of resin restorations can pose a serious esthetic problem. The aim of this study was to evaluate the efficacy of a self-bonding polymer (KISSCARE®) in reducing extrinsic stains in an *in vitro* study model.
- **Methodology:** Thirty-six specimen disks were prepared using a composite resin (Vitalescence: shade A2 and A4), and divided into three experimental groups with different surface coatings: Group 1—Control (no coating); Group 2—Self-bonding polymer (SBP; KISSCARE Concentrated Gel), and Group 3—Composite Sealer (PermaSeal). These groups were further divided into Brushing and Non-brushing subgroups. The specimens in the Brushing groups were brushed daily with 40 strokes in two directions at a 90-degree angle using a toothbrush. Specimens were immersed in a coffee solution at 37°C in a dark environment for 10 days. The color changes of each group were quantitatively measured using a spectrophotometer. Means and standard deviations were calculated, and data were analyzed using ANOVA/Scheffe post-test.
- **Results:** The SBP group showed less color change compared to the Control and the Sealer groups ($p < 0.05$). The Sealer group resulted in greater discoloration compared to the Control and the SBP group ($p < 0.01$).
- **Conclusion:** Application of self-bonding polymers was an effective method of surface coating in reducing staining of restorative resins, especially in the absence of brushing procedures.

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## Introduction

The advent of resin-based composites has offered a remarkable advancement in esthetic dentistry. Today, resins are the materials of choice for restorations in the anterior teeth. Resin materials must meet important physical properties, including compressive and tensile strength, hardness, thermal characteristics, polymerization shrinkage, water sorption and solubility, and wear resistance.[1] The esthetic properties of a restoration play a significant role in achieving ultimate clinical success. One of the most essential characteristics of a resin material is color stability to achieve an esthetically successful clinical outcome.[2,3] Composite restorations require replacements due to failing esthetics, marginal staining, microleakage, wear, and recurrent caries.

Color stability is unquestionably one of the most important clinical esthetic requirements easily measured by patients. Color changes to existing restorations, especially affecting the anterior teeth, would severely compromise esthetics. A resin restoration that is considered highly esthetic at the time of placement could be regarded as unacceptable due to surface and marginal staining attributed by time-dependent surface change of the restorative material, and extrinsic staining from diet and smoking habits of patients.[4,5]

Discoloration of resin restorations can be a serious esthetic problem, and reflects the susceptibility of polymers to staining. Previous studies have indicated that color stability of resin restorations is influenced by different finishing treatments of the material surfaces.[6-8] The surface finishing affects the overall surface roughness attributing to staining and plaque accumulation, which could result in discoloration and secondary caries requiring replacement of restorations.[9,10]

A suggested solution to reduce the staining of resin restorations is the application of a self-bonding polymer (SBP) made of poly(dimethyl siloxane) as a non-stick protective coating. This SBP provides a mono-molecular layer of an inert non-stick finish to discourage staining and facilitate cleaning. Application of SBP on a solid surface results in changes in chemistry of the surface to which it is applied, but provides no mechanical protection. It has the advantage of producing a thin coating 120 Angstroms (0.012 micron) in thickness, thereby providing a virtually invisible and undetectable barrier in an oral environment.[11]

The aim of this accelerated staining study was to investigate the efficacy of this self-bonding polymer in reducing extrinsic stains of resin restorations using a computer spectrophotometer.

## Materials and Methods

### *Preparation of Resin Samples*

A total of 36 specimens were made by incrementally placing a composite resin material, Vitalescence® Shade A2 and A4 (Ultradent, South Jordan, UT, USA), on a clear glass slab to obtain a uniform surface roughness among samples. The specimens were light-polymerized for 40 seconds after each increment by use of a light-polymerizing unit (Demetron Research Corporation, Danbury, CT, USA) at 470 mW/cm2. One light-polymerizing unit was used for all specimens. The material was placed between two glass slabs during the final light-polymerization process to obtain a smooth flat surface for the specimens to a final thickness of 2.0 ± 0.1 mm, as measured by a caliper (Precision Equipment Co., Boston, MA, USA).

The resin samples were divided into three experimental groups: Group1 (Control); Group 2 (SBP); and Group 3 (Sealer). Resin samples in Group 1 had no coatings applied to the surfaces. KISSCARE® Concentrated Gel (KISS-COTE Inc., Tampa, FL, USA) was applied to the testing surfaces of the resin samples in Group 2. For each resin sample, 10 mg of the KISSCARE was

applied from a prophy cup using a slow-speed handpiece to spread the gel completely over the sample surfaces. Any excess of the material which could be removed was wiped off with gauze. Only light pressure was required to assure that the surface was thoroughly wetted with the gel. Resin samples in Group 3 (Sealer) were prepared using a composite sealer Permaseal® Composite Sealer and Bonding Agent (Ultradent, South Jordan, UT, USA) according to the manufacturer's instructions, which involved etching of the resin surfaces for five seconds with Ultra-Etch® 35% phosphoric acid (Ultradent, South Jordan, UT, USA), then rinsing and drying.

### *Staining Solution*

To prepare a standard solution of coffee, 10 g of coffee (Starbucks, Seattle, WA, USA) were put on a filter paper, and 180 ml boiled distilled water was passed through the coffee. This solution was allowed to cool to 37° ± 1°C. All samples were immersed in water for 24 hours, and then in coffee solution for 10 more days at 37° ± 1°C in an incubator. The controls were stored in distilled water in a dark environment at 37° ± 1°C. During the measurement period, the staining solutions were changed once a day. After removal from the staining solution, samples were rinsed in distilled water and dried with tissue paper. After color measurements at the time intervals indicated, the specimens were reimmersed in newly made staining solutions.

### *Brushing Treatment*

The sample discs assigned to the brushing groups were brushed daily with a soft-bristle toothbrush (Oral-B Laboratories, Boston, MA, USA), moistened with distilled water, for 40 strokes in two directions at a 90-degree angle. Brushing procedures were performed for all samples by one operator using light hand pressure. Afterwards, the samples were rinsed with distilled water.

### *Color Measuring Instrument*

Spectrophotometric measurements were made using a multi-spectral camera system (Handy-MSC; Olympus, Tokyo, Japan). This spectrophotometer uses a new technique of multi-band image acquisition, with built-in LED lamp in the measuring head as a light source. The acquired multi-band image data estimates spectrum and colorimetric values using an original algorithm. Eight LED lamps (Olympus, Tokyo, Japan) were used as a source of illumination. The area of illumination was approximately 20.0 mm in diameter, with a central area 15.0 mm in diameter. Spectral data acquisition required about 0.2 seconds. The spectrophotometer used in this study has 45°/0° geometry, and is accurate to less than ± 0.1 ΔE for repeated measurements. Prior to specimen color measurement, a calibration was performed with a standardized calibration tile (Olympus, Tokyo, Japan). The measuring head was placed on the surface of the ob ject, and the display confirmed the object and the area to b measured. This instrument generates a multi-spectral image tha is a digital image of an entire object that features spectral dat for each pixel, and saves it to a computer (CF-W2, Panasonic Tokyo, Japan) for analysis. The image is expanded on the com puter, and the area of interest for spectral analysis can be selected An actual measurement is performed for each area chosen fron the display image. Reflectance values ranged from 380 nm to 78( nm at 1.0 nm intervals. CIELAB color coordinates L* (Light ness), a* (Redness) and b* (Yellowness) were provided.[12]

### *Colorimetric Measurements*

Quantitative color measurements were performed using a computerized spectrophotometer (MSC-2000; Olympus, Tokyo, Japan) just prior to immersion in coffee solution, and after days 1, 3, 5, 7, and 10. During the test intervals, specimens were rinsed with distilled water for one minute to remove the coffee solution, and blotted dry prior to each measurement. The color of each specimen was analyzed by use of the spectrophotometer, and values were calculated with the CIELAB system. Instrumental color measurements were made according to the color difference value ΔE, and color coordinates L* (Lightness), a* (Redness), and b* (Yellowness). According to the CIELAB units, close color mismatch was in the range of 2 to 4 ΔE units. A ΔE of less than 1 was considered excellent, and that of over 3.6 was considered a clinically distinguishable color difference.[13-15] Color difference ΔE was calculated according to the following equation:[16]

Pre-immersion: $L^*_0$, $a^*_0$, $b^*_0$

Post-immersion: $L^*_i$, $a^*_i$, $b^*_i$

$$\Delta E = [\{L^*_0 - L^*_i\}^2 + \{a^*_0 - a^*_i\}^2 + \{b^*_0 - b^*_i\}^2]^{1/2}$$

L = lightness

a, b = chroma

$i$ = 1, 3, 5, 7, 10 days

Three measurements were performed for each specimen, and the mean value was calculated. The data were analyzed using ANOVA/Scheffe post-test.

## Results

Descriptive statistics for the study population are summarized in Table I. The mean color difference for Shade A2 Brushing samples were 18.69 ± 5.98, 15.78 ± 3.84, and 36.62 ± 3.66, for the Control, SBP, and Sealer groups, respectively. The Shade A2 Non-brushing samples exhibited the mean values of 20.53 ± 6.59, 16.73 ± 4.32, and 38.42 ± 2.47, for the Control, SBP, and Sealer groups, respectively. The color difference was greater for the Non-brushing subgroup than for the Brushing subgroup.

A slightly lower color difference was observed in the Shade A4 group compared to the Shade A2 group. The mean color

**Table I**

Color Analysis Measure in Color Difference, ΔE (Mean ± SD)

| | Brushing | | | Non-Brushing | | |
|---|---|---|---|---|---|---|
| | Control | SBP | Sealer | Control | SBP | Sealer |
| Shade A2 | 18.69 ± 5.98 | 15.78 ± 3.84 | 36.62 ± 3.66 | 20.53 ± 6.59 | 16.73 ± 4.32 | 38.42 ± 2.47 |
| Shade A4 | 13.91 ± 3.52 | 10.47 ± 2.77 | 20.27 ± 2.33 | 15.00 ± 4.75 | 9.19 ± 2.98 | 19.85 ± 1.61 |

difference values for Shade A4 Brushing samples were 13.91 ± 3.52, 10.47 ± 2.77, and 20.27 ± 2.33, for the Control, SBP, and Sealer groups, respectively. In the Non-brushing samples, the mean values were 15.00 ± 4.75, 9.19 ± 2.98, and 19.85 ± 1.61, respectively.

The color measurements performed using a computerized spectrophotometer just prior to immersion in coffee solution and after days 1, 3, 5, 7, and 10 revealed that the Sealer groups (Brushing and Non-brushing subgroups) exhibited more discoloration compared to both the Control and SBP groups, as shown in Figure 1.

Color analysis made at the end of 10 days showed that the SBP group demonstrated significantly less discoloration compared to the Sealer group in all groups tested ($p < 0.01$), as illustrated in Figure 2. The SBP group also exhibited less color change that was statistically significant compared to the Control group in all groups, except for the Shade A2 Brushing subgroup. There was no significant difference between the Control and SBP group for the Shade A2 Brushing subgroup. In that subgroup, the Sealer group had a statistically significant discoloration ($p < 0.01$) compared to both the Control and Sealer groups, even starting at day 1 of the experiment. However, in the Non-brushing subgroup, the

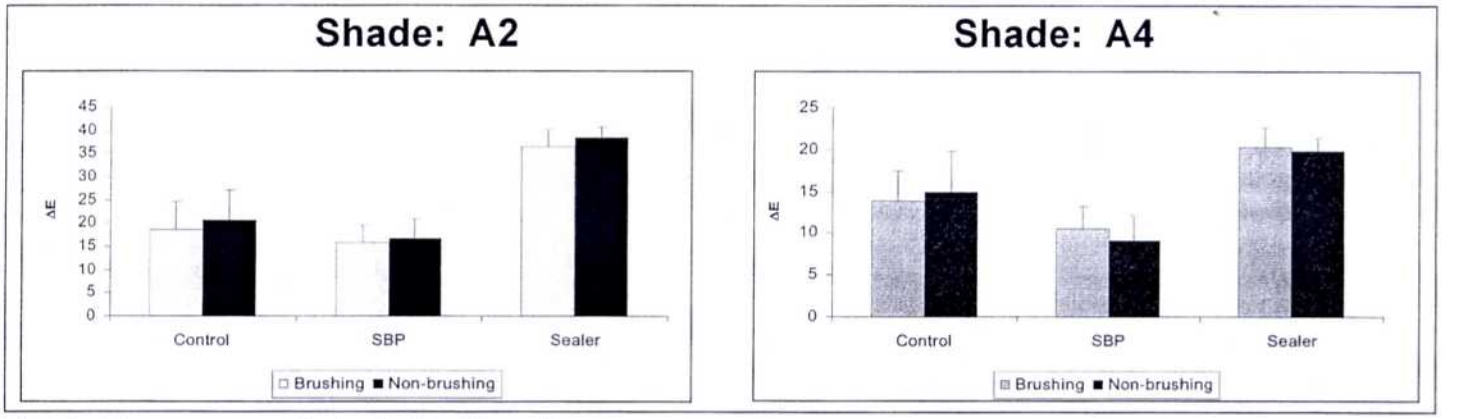


**Figure 1.** *Color measurement of discoloration (ΔE), Mean ± SD.*

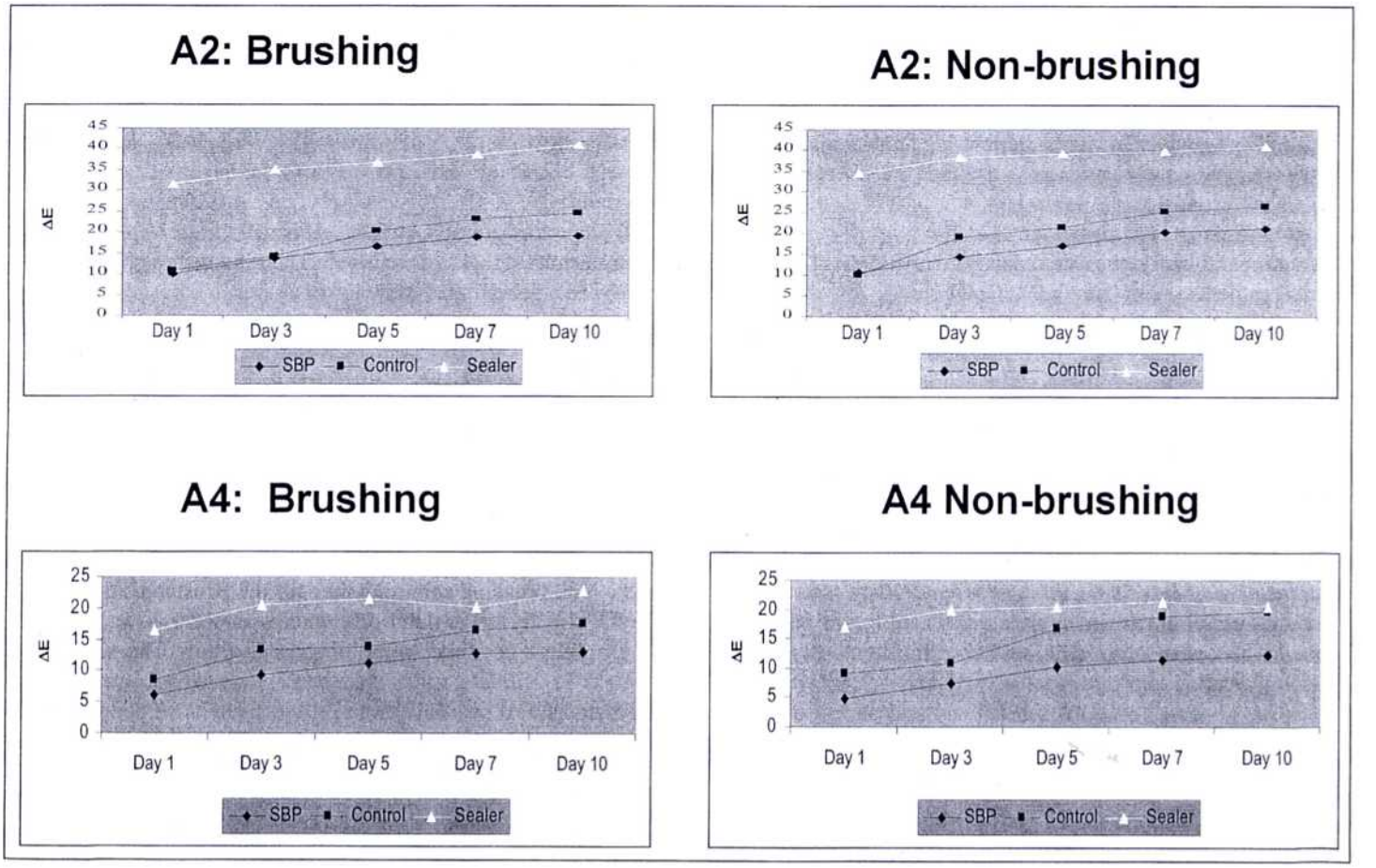


**Figure 2.** *Color difference (ΔE) measured at days 1, 3, 5, 7, and 10.*

Control showed a discoloration starting at day 3 compared to the SBP group that was statistically significant at $p < 0.05$.

## Discussion

Finishing and polishing of composite resins with carbide or diamond burs can introduce microscopic fractures into the surface and/or degrade the matrix through heat generation.[1] This results in a decrease in mechanical properties and wear resistance of resin surfaces requiring replacement of restorations. Application of low viscosity unfilled resin or sealer to coat the resin restorations by filling microscopic defects has been a popular method in clinical dentistry. The purpose is to improve the wear characteristic, increase surface hardness, and prevent marginal microleakage. This method of surface treatment is also used to reduce staining of resin surfaces by providing a smooth protective layer and covering any irregularities in the surface.

Results from this study indicated that application of unfilled resin sealer produced greater discoloration compared to the Control and the SBP groups that were statistically significant. This may have been attributed to the inability to produce a uniform thickness of unfilled resin coating, creating an unwanted rough/irregular surface. A rough surface is generally considered more susceptible to staining, contributing to more surface area for mechanical retention. Surface roughness is known to be one of the major factors in discoloration of poorly polished restoration surfaces.[17,18] Highly polishable microfilled composite resin materials are most frequently recommended in anterior restorations due to their ability to produce a smoother surface and be effective in stain resistance.

Incomplete polymerization of the resin matrix may have a critical part in surface staining of resin restorations. It is a crucial reason for the decrease in physical characteristics of restorative resins. Research studies demonstrated that areas of incompletely polymerized composite resins were identified by absorption of color dye on the surface of composite materials, indicative of vulnerability of unpolymerized resin surfaces to staining.[19] Incomplete polymerization could also pose a risk for water sorption and solubility of resin materials, further jeopardizing stain resistance.[20] Incomplete polymerization could have occurred in the Sealer experimental group causing greater discoloration in those samples.

The results from this study showed that the lighter shade resin (A2) samples exhibited a greater color difference than the darker shade (A4) samples. This finding is also similar to clinical observations in which the change in discoloration is more noticeable in lighter shade restorations. Although there was no statistical difference compared to the Brushing and Non-brushing subgroups, data indicated that greater discoloration existed in all groups tested for the Shade A2 Brushing samples. The Non-brushing subgroups showed more discoloration for the Shade A2 group, indicative that patients with poor oral hygiene would end up with a more visible amount of discoloration.

Application of KISSCARE in the SBP group did not require etching or an additional light-cured polymerization step that were required of the Sealer group and could have eliminated a major factor in staining. The long-term validity of this coating is, however, unknown, although our accelerated study had signifi cantly less staining that continued until day 10 of the experimen The wear resistance affected by brushing is another factor tha needs to be explored further.

## Conclusions

Application of self-bonding polymers is an effective metho of surface coating in reducing staining of restorative resins especially in groups without brushing procedures. Composit sealers appeared to be the least desirable method for reducin stain.

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