

Surface Sealant Effect on the Color Stability of a Composite Resin Following Ultraviolet Light Artificial Aging

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Clinical Relevance

Surface sealants may be effective in perceptibly extending the original color of the restoration, within a clinically acceptable range, for a protracted period of time; however, the material as well as the restorative (composite resin) should be evaluated during routine oral hygiene or examination appointments for color stability and/or surface defects.

SUMMARY

Objective: To examine how exposure to accelerated artificial aging (AAA) stimuli (ultraviolet [UV] light) affects the color stability of a composite resin following surface sealant (SS) application.

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Methods and Materials: A total of 30 cylindrical composite resin (Esthet-X) discs were prepared using Teflon-coated rings. The treatment groups, defined by different SS (Seal-N-Sine, PermaSeal, OptiGuard, Biscover LV, and DuraFinish) use, were divided into five groups of six discs each. The discs were subjected to baseline color measurements followed by measurements after surface sealant application (specular included component [SCI] and specular excluded component [SCE]) using a spectrophotometer. Three measurements (SCI and SCE) were performed for a total of 18 readings (test surface) per specimen group. All specimens were then exposed to a UV light source for a total of 382 hours. Color readings of the specimens were again recorded for each group. Quantitative color measurements were executed using Commission Internationale de l'Eclairage L*a*b* calculations.

Results: Baseline color measurements of the composite resin discs, following the AAA exposure protocol, revealed no significant differences. A comparison of the composite resin

discs before and after SS application (without UV light exposure) showed statistically significant differences using both SCI and SCE measurement criteria. Although significant differences were encountered between the ΔL^* , Δa^* , Δb^* , and ΔE parameters, all specimens (groups) were within the clinically acceptable range ($1.0 < \Delta E \leq 3.3$). Again, statistically significant differences were noted (ΔL^* , Δa^* , Δb^* , and ΔE parameters) for all specimen groups receiving SS application, utilizing both SCI and SCE measurements, following exposure to UV light. All groups were within the clinically acceptable range ($1.0 < \Delta E \leq 3.3$), except the Durafinish group. The Durafinish SS group experienced significantly greater ($p < 0.001$) overall color change (SCI and SCE) following UV light exposure. An intergroup comparison following UV exposure revealed that the Permaseal, OptiGuard, and Seal-n-Shine SS groups displayed the least amount of color change statistically but not necessarily always perceptibly significant, while the Durafinish group exhibited the greatest color change statistically and perceptibly.

Conclusions: The color stability of a composite resin, including the addition of most SSs, was not affected perceptibly by UV light exposure.

INTRODUCTION

A direct correlation can exist between the final esthetic appearance of a dental restoration and the performance of the finishing and polishing procedures.¹⁻⁴ Application of specific formulation liquid polishing agents has been recommended supplementary to immediate insertion and finishing of direct placement resin-based restoratives. This treatment has been suggested to overcome possible deficiencies associated with physical properties of the materials and, perhaps, operator imprecision.^{5,6} These post-restorative covering agents have been referred to as rebonding/glazing/liquid polishing agents or, more specifically, surface sealants (SSs).^{5,6} Such sealants are applied to the restoration surface and surrounding tooth structure, seemingly promoting improved marginal sealing while also permeating surface microdefects and/or voids formed during material insertion and polymerization.^{5,6}

Traditional dentin bonding agents and pit-and-fissure sealants have attempted to serve in this capacity in the past. However, clinical performance is directly related to the factors of viscosity and/or wettability (fluidity) of the individual formulations,

and thus these materials were not necessarily viable alternatives.⁷ Currently, SSs contain low-viscosity unfilled resins and other low-molecular-weight monomers as well as extremely efficient photoinitiators and modifiers.^{5,6,8} For effective utilization and long-term success of these agents, the surface tension of the SS and the incumbent surfaces to be restored should be equivalent if adequate wetting and, in turn, adhesion are expected.⁹

Color instability of resin-based restoratives can also be affected by physicochemical material alterations from exposure to different aging stimuli.^{8,10} Experimental accelerated artificial aging (AAA) protocols consist of submitting restorative materials to intervals of contact to ultraviolet (UV) irradiation, hygroscopic, and/or temperature extremes comparable to long-term exposure periods produced by natural external environments.¹¹⁻²⁴ Therefore, *in vitro* AAA methods can predict *in vivo* modifications in dental resins (ie, color instability), conceivably foretelling clinical conditions.¹¹⁻²⁴

Quantitatively defining color change for a tooth-colored restoration has been directed by the Commission Internationale de l'Eclairage (CIE) $L^*a^*b^*$ three-dimensional color space measurement system in which the L^* axis measures luminosity or lightness ranging from 0 (black) to 100 (white), the a^* coordinate measures redness ($a > 0$) or greenness ($a < 0$), and the b^* coordinate measures yellowness ($b > 0$) or blueness ($b < 0$).²⁵⁻²⁷ Quantitative measurement of the total change in color (ΔE) incorporates a specific formula for qualitative application pertaining to perception and acceptance thresholds.²⁵⁻²⁷

This study evaluated the effects of a specific type of AAA protocol, UV light irradiation, reporting two specific light reflectance measurements—specular included component (SCI) and specular excluded component (SCE)—for the color stability of a composite resin before and after SS application. The hypothesis of the study was that significant change in color qualities of a composite resin, incorporating the tested SSs, occurs following exposure to the AAA protocol.

METHODS AND MATERIALS

Treatment Groups and Specimen Preparation

The experimental groups (Table 1) were defined by the different SS materials, including Seal-N-Sine (Pulpdent Co, Watertown, MA, USA), PermaSeal (Ultradent Products Inc, South Jordan, UT, USA), OptiGuard (Kerr Co, Orange, CA, USA), Biscover LV

Table 1: Product (Group), Manufacturer, and Composition of Surface Sealants Used

SS Group	Manufacturer	Composition
A: Seal-N-Sine	Pulpdent Co (Watertown, MA, USA)	Uncured acrylate ester monomers, silica
B: PermaSeal	Ultradent Products Inc (South Jordan, UT, USA)	Bis-GMA, TEGDMA, DMAEMA
C: OptiGuard	Kerr Co (Orange, CA, USA)	2,2'-ethylenedioxydiethyl dimethacrylate, TEGDMA, CQ
D: Biscover LV	BISCO Inc (Schaumburg, IL, USA)	Ethanol, PENTA
E: DuraFinish	Parkell Inc (Edgewood, NY, USA)	MMA, CQ

Abbreviations: Bis-GMA, bisphenol A glycidyl methacrylate; TEGDMA, triethylene glycol dimethacrylate; DMAEMA, 2-dimethylaminoethyl methacrylate; CQ, camphorquinone; PENTA, dipentaerythritol pentaacrylate; MMA, methyl methacrylate.

(BISCO Inc, Schaumburg, IL, USA), and DuraFinish (Parkell Inc, Edgewood, NY, USA).

Thirty cylindrical discs (10.0-mm inner diameter×1.0-mm thickness) were prepared from Teflon-coated rings using Esthet-X HD (Dentsply Caulk, Milford, DE, USA), shade A3 micromatrix composite resin. Each ring/material insertion was covered with transparent polyethylene terephthalate matrix strips (Mylar DuPont Teijin Films, Chester, VA, USA) on each side to ensure a uniform finish. The composite resin/matrices were compressed between two microscopic glass slides with pressure applied from a 10-pound stainless-steel weight in order to extrude any excess material. Each composite resin insertion was polymerized through the slides, from each side, for 40 seconds with a Valo (Ultradent) light-emitting diode curing light, thus yielding one disc. The light intensity (>800 mW/cm²) was verified with a Coltolux Light Meter (Coltene, Inc, Mahwah, NJ, USA).

Color Measurement and Accelerated Artificial Aging Protocol

The composite resin discs were randomly divided into five treatment groups of six discs per group (groups A-E) based on the type of SS covering material. Both sides of each disc received an initial transparent matrix (Mylar) surface finish. Prior to SS application, baseline color measurements were performed for each composite resin disc, including a total of 18 measurements per group (one side served as a test surface, while the other side was assigned as an identification surface, appropriately marked). Each disc was measured for two separate color parameters: SCI and SCE against a black background using a Konica Minolta spectrophotometer CM-5 (Konica Minolta Sensing Americas, Inc, Ramsey, NJ, USA). Afterward, the test side of each disc was etched or “cleaned” using Ultra-Etch (Ultradent) 35% phosphoric acid solution, followed by coating with a respective SS, and light cured for 20 seconds.

The specimens were wiped/buffed with a lint-free clean cloth to remove any oxygen-inhibited layer or other debris. The transparent matrix side (marked surface) remained undisturbed. Usage of all restorative materials strictly adhered to manufacturer directions regarding application, polymerization, and handling. Following application of SSs, color measurements were performed for the specimens. All specimens were immediately exposed to the AAA protocol, consisting of a UV light chamber (“mirrored” superior/inferior surfaces) containing four fluorescent bulbs (nine watts each) for a total of 382 hours. A custom-fabricated holder was used to support the specimen discs in a vertical orientation in order to receive appropriate light exposure (approximately 50 millimeters [mm] from the light source). The specimens were again measured for color, following identical procedures. Regarding the UV light exposure protocol of the different dental materials, the authors were attempting to simulate a clinical experience. During SS application of the composite resin disc, a covering agent or barrier (clear matrix, gel) was not utilized, and therefore creation of an oxygen-inhibited layer was probable.

The present study included exposure of the material specimens to 24 hours of UV light per day using artificially induced UV irradiation for a total of 382 hours of UV exposure.

All color measurements were analyzed using CIE L*a*b* system criteria. The mean L*a*b* values were calculated for each composite resin and SS group. The CIE 1976 Delta E formula²⁵⁻²⁷ $\Delta E_{ab}^* = [(\Delta L_{ab}^*)^2 + (\Delta a_{ab}^*)^2 + (\Delta b_{ab}^*)^2]^{1/2}$ for total color change was chosen rather than more current but increasingly complex versions (CIE1994, 2000). Measurements before and after application of the SSs and exposure to AAA were completed noting the following clinically applicable thresholds: $\Delta E_{ab} < 1.0$ = excellent match; $1.0 < \Delta E_{ab} \leq 3.3$ = acceptable; and $\Delta E_{ab} > 3.3$ = clinically unacceptable (mismatch) for color comparisons.²⁸

Table 2: ΔL^* , Δa^* , Δb^* , and ΔE (means and standard deviations) of the specimen groups tested following addition of the surface sealants (specular included component [SCI] and specular excluded component[SCE]) (statistically significant intergroup differences also included)^a

	Sample Size	ΔL^*	Δa^*	Δb^*	ΔE
Group (SCI)					
A	18	0.65 (0.4008) ABC	0.11 (0.0711) A	0.55 (0.6056) ABC	1.06 (0.3574) AB
B	18	1.06 (0.3885) B	0.15 (0.0695) A	0.78 (0.4079) AB	1.38 (0.3845) ACD
C	18	0.90 (1.2470) B	0.13 (0.2396) A	1.11 (2.0160) A	1.57 (0.3593) CD
D	18	0.35 (0.6735) A	0.18 (0.1230) A	-0.19 (1.1410) B	1.20 (0.6751) BC
E	18	0.22 (0.7094) C	0.55 (0.2535) B	-1.10 (1.3000) D	1.80 (0.6760) D
Group (SCE)					
A	18	0.05 (0.8226) AC	0.13 (0.1289) A	0.90 (0.2817) A	1.18 (0.3655) A
B	18	1.07 (0.8420) B	0.15 (0.0896) A	0.71 (0.7009) A	1.61 (0.5110) AB
C	18	1.81 (1.1750) B	-0.08 (0.7083) A	0.35 (1.1740) AB	2.06 (0.9929) B
D	18	0.90 (1.4520) BC	0.16 (0.1593) A	-0.60 (1.4020) B	2.05 (0.9468) B
E	18	0.69 (0.4402) AB	0.55 (0.2979) B	-1.64 (1.2500) C	2.08 (0.9721) B

^a Same letters in each column indicate no statistically significant differences.

Statistical Analyses

Statistical analyses were conducted using parametric one-way analysis of variance and, if applicable, Tukey-Kramer multiple comparison tests to determine statistically significant differences in Δ (ΔL^* , Δa^* , Δb^* , and ΔE) among the materials (groups) tested. All data were submitted for statistical analyses at the $\alpha = 0.05$ level of significance. The statistical calculations were performed using InStat (GraphPad Software, Inc, La Jolla, CA, USA).

RESULTS

Following exposure to UV light, the baseline color change or the overall ΔE of the composite resin discs (without SS application) revealed readings of 1.10 (SCI) and 1.13 (SCE). Although these measurements were numerically statistically significant from the original color of the discs, the readings were in the clinically acceptable range ($1.0 < \Delta E_{ab} \leq 3.3$) for both the acceptance and the perceptibility thresholds. Table 2 shows the ΔL^* , Δa^* , Δb^* , and ΔE mean scores (standard deviations) and statistically significant differences among specimen groups prior to and following SS application, considering both SCI and SCE measurements (prior to UV light exposure). Total overall numerical (statistical) differences, according to the ΔE CIE parameter, were apparent; however, clinically perceptible changes (ΔE) were not revealed for the specimens (all groups) following SS application. For intergroup comparisons, statistically significant differences were exhibited between specimen groups, with group E (Durafinish) having revealed the greatest overall numerical color change (ΔE : 2.08) before and after SS application but

again not clinically perceptible. The mean overall color change scores (ΔE) comparing composite discs (groups) before and after SS covering revealed a progression (from least to greatest): $A < D < B < C < E$ for the SCI measurements and $A < B < D < C < E$ for the SCE measurements. Again, these specimen measurements were acquired prior to UV light exposure. Table 3 shows the ΔL^* , Δa^* , Δb^* , and ΔE mean scores (standard deviations) and statistically significant differences between specimens following SS application and UV light exposure, considering both SCI and SCE measurements. Total overall numerical (statistical) color changes, according to the ΔE CIE parameter, were again apparent. Clinically perceptible changes (ΔE) were revealed only for group E (Durafinish), yielding a ΔE of 4.02 (SCI) and 4.49 (SCE). Statistically significant differences were exhibited between specimen groups. Groups A, B, and C (Seal-n-Shine, Permaseal, and OptiGuard) displayed the least amount of color change, including statistically significant ($p < 0.05$) differences. Groups D and E showed the greatest color changes, with group E (Durafinish) having revealed statistically significant ($p < 0.001$) as well as clinically perceptible differences following UV exposure. The mean group overall color change scores (ΔE) following SS application/UV exposure revealed a progression (from least to greatest): $B < A < C < D < E$ for both SCI and SCE measurements.

DISCUSSION

The primary objective of the present study was to measure the color stability of a direct placement composite resin restorative before and after applica-

Table 3: ΔL^* , Δa^* , Δb^* , and ΔE (means and standard deviations) of the surface sealant specimen groups tested following UV light exposure (specular included component [SCI] and specular excluded component [SCE]) (statistically significant intergroup differences also included)^a

	Sample Size	ΔL^*	Δa^*	Δb^*	ΔE
Group (SCI)					
A	18	0.75 (0.140) A	0.15 (0.206) A	-1.44 (0.362) AB	1.66 (0.322) AB
B	18	0.51 (0.137) B	0.14 (0.145) A	-1.16 (0.299) A	1.29 (0.308) A
C	18	0.64 (0.289) AB	0.14 (0.189) A	-1.56 (0.429) BC	1.71 (0.493) BC
D	18	0.73 (0.157) A	0.11 (0.248) A	-1.91 (0.438) C	2.08 (0.401) C
E	18	1.54 (1.538) C	-0.37 (0.359) B	-3.66 (0.529) D	4.02 (0.570) D
Group (SCE)					
A	18	0.54 (0.1643) A	0.15 (0.2144) A	-1.45 (0.4926) A	1.58 (0.503) AB
B	18	-1.26 (0.5986)	0.22 (0.1041) ABC	-0.13 (0.4884)	1.40 (0.553) AC
C	18	0.56 (0.2229) AB	0.16 (0.1926) ABD	-1.56 (0.3460) A	1.69 (0.351) BC
D	18	0.72 (0.2755) AB	0.12 (0.2658) ACD	-2.13 (0.5220)	2.28 (0.530) D
E	18	1.59 (0.3473)	-0.40 (0.3831)	-4.15 (0.6503)	4.49 (0.696) E

^a Same letters in each column indicate no statistically significant differences.

tion of various SSs exposed to a specific AAA protocol (UV light) over a predetermined period of time (simulating long-term clinical conditions). The hypothesis of the study stating that UV light exposure would negatively affect the color qualities of the composite resin and all applicable SS coverings was partially rejected. All groups of composite resin discs (prior to SS application) were well within the clinically acceptable range ($1.0 < \Delta E_{ab} \leq 3.3$) following exposure to the UV light. These results were somewhat contradictory with findings from a previous study¹² showing significant changes to direct placement composite resins (again, without the addition of a SS) following exposure to additional external stimuli. Specimens, including an SS covering, revealed statistically significant differences and, for one SS (Durafinish), clinically perceptible changes following UV light exposure. Specifically, following UV exposure, specimens (including SS application) from groups A-D (SCI and SCE) showed slight increases in luminosity or lightness (ΔL^*), redness (Δa^*), and blueness (Δb^*). Group E (Durafinish) specimens, revealed statistically and clinically significant ($p < 0.001$) increases in lightness (ΔL^*), greenness (Δa^*), and blueness (Δb^*). According to these measurements, group E (SCI and SCE) was the only group to yield clinically (perceptible) unacceptable ($\Delta > 3.3$) matches within the ΔL^* , Δb^* , and ΔE coordinates, given an acceptance threshold of 3.7 ΔE . No relevant studies could be located that employed similar experimental procedures utilizing a UV light exposure protocol and measuring the color stability of composite resins following SS application.

Two separate color (reflectance) measurements were performed for this research study: SCI and SCE. The SCI is considered the “true” color of an object and the measurement of a particular surface, including the reflection of specular and diffuse light, unaffected by the type of surface. The SCE measures the color appearance of an object and excludes any reflected light and thus is more sensitive to surface conditions.^{29,30}

In the present study, each disc received a Mylar surface and visually was comparably smooth and glossy, although microvoids and blemishes were present under higher magnification. The decision was reached that the SCI readings would perhaps be more applicable (considering the imperfect surface conditions), although the results revealed similar color change data for specimens measuring both SCI and SCE parameters.

Technique and material improvements have been effective in changing the performance of esthetic restorative systems; however, numerous factors can induce color instability, including the specific components of the restorative (resin matrix, filler particles), which can affect the physical characteristics, that is, the modulus of elasticity and coefficient of thermal expansion, which can, in turn, alter the hardness and/or abrasion resistance, bond strengths, and the ability of the material to resist microleakage of contaminants at the tooth/material margin.^{12,31-35} Additional material variables include the degree of conversion of carbon bonds and the influence of photoinitiators and modifiers.^{12,31,36-38} Color change as a consequence of external influences includes postinsertion finishing/polishing procedures, oral

habits, absorption and adsorption of extrinsic coloring agents (food colorants), dietary regimens (staining), polymerization light limitations (wavelength and intensity), fluctuations in temperature and hygroscopic absorption, and diverse ambient UV light sources.^{1-4,12-27,39-48}

Fluorescent tubes used for illumination produce a spectrum of UV radiation (UVA) with wavelengths from 315 to 400 nm, with irradiance measured in milliwatts per centimeter squared (mW/cm^2).^{49,50} The irradiation chamber utilized in the present study consisted of four nine-watt (36 watts total) fluorescent lamps with a peak wavelength of 365 nm, producing a UV index (UVI) of 1.5. The UVI measures the level of a source of radiation and is reported as “exposure category” (low to extreme) and corresponding “UVI range” (<2-11+).⁵¹ Comparison to the sun’s energy irradiance would be problematic and perhaps unattainable due to influential factors including elevation, cloud cover, ground reflection, ozone levels, latitude, and altitude.⁵¹

In vitro AAA methods have been used extensively, testing the physical properties of dental materials (composite resin) and thus presumably foretelling the long-term clinical effects from different stimuli, such as visible and UV light, humidity (water storage), and temperature (thermocycling).^{8,10-24} The stresses placed on the composite resin constituents, specifically the organic matrix and inorganic filler particles, can presumably cause alterations in the mechanical and optical properties.¹³ There appears to be very little standardization in the literature regarding different AAA exposure periods necessary for alteration of composite resin characteristics (color change). Studies conducted by Drubi-Filho and others¹⁸ and Pires-de-Souza and others¹⁹ have utilized combination exposure cycles of temperature and UV light for varying periods of time (384 vs 8 hours, respectively). A study conducted by Furuse and others¹⁴ subjected composite resins to different “photoaging” periods of 0, 24, 72, 120, and 193 hours in order to detect color changes. Other studies testing different direct placement tooth-colored restoratives exposed specimens to 100% relative humidity (water bath at dissimilar temperatures) and visible/UV light irradiation for periods of up to 300 hours, which was equated to one year of clinical service.^{12,24} Finally, a study protocol conducted by Heydecke and others¹⁵ subjected porcelain veneers to 300 hours of AAA consisting of UV light and water spray from an apparatus referred to as a “Weather-O-Meter.” The manufacturer of the Weather-O-Meter claimed that 300 hours of AAA

exposure was equivalent to one year of clinical service. Although dental restorations are subjected to varying external stimuli, including combinations of different qualities and quantities of light, humidity, temperature, colorants, and foodstuffs during the life of the material, there is probably minimal evidence-based information supporting positive correlations between *in vivo* and *in vitro* conditions.

Several important factors must be noted regarding the quality of polymerization for a particular resin-based substance, including the material thickness and shade; light source, intensity, and wavelength spectrum generated; the time and distance of exposure; and the individual material photoinitiator’s absorption target or peak wavelength (nm).^{38,52,53} The light source includes the wattage or the amount of electrical power consumed. The strength or intensity refers to the measured output of light energy. Light is also measured according to the spectral output or wavelengths in nanometers and is revealed in a scale of visible and invisible energy.^{49,50} The light intensity is an important component regarding polymerization of resin-based dental materials; however, the wavelength spectrum of light irradiation should closely match the absorption spectra of the photoinitiator incorporated in the material.^{38,53} Peak activation of a resin-based material depends on the photoinitiator wavelength and the energy of the photons (wavelength) of the polymerization source. The photoinitiators contained in the material absorb the incoming energy from the light source and precipitate conversion of the polymer composition.⁵³

Surface sealants have been advocated as adjuncts for completion of the restoration finishing and polishing procedures.^{5,6} Potential benefits include increasing the seal at the tooth/restoration interface or margin, thereby preventing or decreasing the occurrence of microleakage. Surface sealants also serve to saturate the material surface, filling any defects, voids, and/or irregularities and increasing wear and stain resistance and thus enhancing esthetic qualities.^{33-35,54-61} However, very limited research exists concerning the use of these materials and the extent to which they improve the longevity and appearance (color stability) of a composite resin restoration.⁴

Regarding the present study, an interesting, but not unexpected phenomenon occurred following the polymerization of SSs onto composite resin restoration surfaces. The formation of a sticky oxygen-inhibited layer following light polymerization having been exposed to ambient air was quite noticeable.

This surface layer of unreacted monomers was formed from the absence of the use of a clear matrix or layer of unreactive substance (eg, glycerin gel). Polymerization of the underlying material, which permeates into the surface irregularities and defects, was accomplished; however, the overlying surface film layer of the material was unreactive and uncured to varying degrees (ie, the formation of an oxygen-inhibited layer).⁶² Although the initial appearance was a glossy surface, complete polymerization had not occurred. With the formation of the oxygen-inhibited layer, the SS addition could be considered a negative attribute. As this process can occur with regularity, some manufacturers tout their products as containing ingredients producing a very thin oxygen-inhibited layer or film thickness following polymerization. However, the routine usage by a dental professional of a covering barrier (matrix and/or gel) placed over the surface sealant prior to light polymerization is probably not a realistic expectation.

According to Ferracane and others,²⁰ the formation of an oxygen-inhibited layer in a polymerized material can precipitate into the eventual formation of yellow-colored peroxides, with a material that contains greater than 35% unconverted bonds. In the present study, although statistically significant differences were noted between several of the groups regarding the parameters of ΔL^* , Δa^* , Δb^* , and ΔE , most of the significant perceptible color changes involved Δb^* or increases in the blueness of a material following the AAA protocol.

CONCLUSIONS

Within the limitations of this *in vitro* study, the following conclusions were surmised:

- 1) Following the AAA exposure protocol, the composite resin discs, without the inclusion of SS application, revealed no statistically or perceptibly significant differences in overall color change or ΔE , considering both SCI and SCE color measurements.
- 2) Following application of surface sealants to the composite discs, statistically significant changes in color were exhibited; however, clinically perceptible changes were not evident. Intergroup comparisons following SS application revealed that the Durafinish group, although statistically but not clinically significant, had the greatest degree of color change.
- 3) Following exposure to the UV light protocol, using both SCI and SCE measurements, group E (Durafinish) experienced significantly greater ($p < 0.001$) overall color change (ΔE) compared to the other groups. Also, group E (Durafinish) specimens, revealed statistically significant ($p < 0.001$) increases in lightness (ΔL^*), greenness (Δa^*), and blueness (Δb^*) and was the only group to yield clinically (perceptible) unacceptable ($\Delta > 3.3$) matches within the ΔL^* , Δb^* , and ΔE coordinates.
- 4) Following the AAA exposure protocol and measurement using both SCI and SCE parameters, groups A-C (Seal-n-Shine, Permaseal, and Opti-Guard) displayed the least amount of overall color change (although not necessarily always statistically significant) compared to groups D and E. A statistically significant ($p < 0.001$) difference was shown between specimen groups D and E.

The study hypothesis was partially rejected. Only one of the experimental groups revealed statistically and clinically perceptible color changes following UV light exposure, while no statistically significant or clinically perceptible differences were revealed by the composite discs alone following light exposure. For the majority of the groups tested, application of SSSs as “polishing” adjuncts following insertion of composite resin restoratives and exposure to a specific AAA protocol provided long-term color stability—if perception and acceptance thresholds are considered as the key indicator instead of statistical significance before and after.

Conflict of Interest

The authors of this article 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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