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Research Article

Comparative Evaluation of the Color Stability of Three Light-Cured Composite Resins after Exposure to Common Beverages

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ABSTRACT

The objective of this study was to use the CIE L*a*b* color system and spectrophotometric analysis to assess the color stability of three light-polymerizing resin composites: Clearfil AP-X Esthetics (Kuraray), ELS Xetra (Saremco), and Neo Spectra™ ST (Dentsply Sirona) following exposure to common beverages (coffee, tea, and water). Ninety specimens (n = 30/composite) were prepared and cured according to the manufacturers' instructions. Each composite group was divided into three subgroups (n = 10) and immersed in coffee, tea, or distilled water. Color measurements were taken at baseline, 10 days, and 20 days using the VITA Easyshade® spectrophotometer. The ΔE (color difference) values were calculated, and results were statistically analyzed using the Wilcoxon signed-rank test, one-way Analysis of Variance, and Tukey's *post hoc* tests. ΔE values were converted to National Bureau of Standards (NBS) units to assess clinical perceptibility. The result shows that coffee was the most effective staining agent, with all composites showing substantial color change over time ($P < 0.05$). Clearfil had the highest ΔE values (5.70 during 20 days in coffee), followed by ELS Xetra (6.20), while Neo Spectra had the least discoloration (5.10). Tea generated substantial discoloration, whereas distilled water produced negligible changes. NBS conversion showed that coffee immersion caused "very much perceptible" alterations in all composites. The color stability of composite restorations is greatly impacted by the staining potential of liquids, especially coffee. Clearfil and ELS Xetra were more prone to discoloration, whilst Neo Spectra showed better resilience. These results highlight how crucial dietary advice and composite selection are to attaining long-term esthetic results.

Keywords: Color stability, spectrophotometry, composite discoloration, Clearfil AP-X esthetics, ELS Xetra, neo spectra

INTRODUCTION

Dental practice has been completely transformed by advancements in conservative restorative materials and adhesive techniques. More conservative methods of tooth preparation have been made possible by advancements in esthetic techniques and the potential to attach the restorative material to the dental surface. The quality of the filler material has a good correlation with the restoration's success.[1] Because resin composites have superior esthetic qualities and a strong attachment with the tooth, they are typically employed in conservative dental restorations rather than amalgam. Discoloration frequently necessitates the expensive and time-consuming revision or replacement of composite restorations.[2]

New composite resin materials have been developed as a result of significant advancements in the science and technology of composite dental restorative materials.[3] After being placed in the oral cavity, composite dental materials have been developed to improve durability and color stability.[4] Different composite resins have been introduced by manufacturers to meet the following requirements: Stability, precise color matching, and light-curability.[5] Condensable/packable, flowable, microhybrid, and nanocomposite materials are examples of these resin materials.[6] The most frequent cause of composite repair replacement, discoloration, is typically brought on by dietary items, such as tea and coffee.[7] The degree of water absorption and the hydrophilicity of the matrix resin may be the cause of discoloration in restorative materials. A composite resin may change color if it has the ability to absorb additional fluids in addition to water.[8] In this case, the size and distribution of the filler particles as

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well as the makeup of the resin matrix are crucial.[9] The composite's color stability and polymerization properties can be impacted by the photoinitiator system.[10] The color stability of resin composite restoration materials is influenced by a number of factors, including patient habits, such as consuming beverages that include stains, such as tea and coffee, and other beverages that contain stains in their ingredients. These staining agents cause pigments to be absorbed, changing the material's color. Numerous elements, including as pH, matrix, kind of chemical bond filler, water uptake, and copolymer composition, influence how quickly the degradation reaction proceeds. Because it affects the rate of breakdown during catalysis, low pH is specifically undesirable for hydrophilic resins. Patients frequently ask dentists about the anticipated longevity of esthetic restorations and whether their eating habits can affect the restorations' clinical survival and quality. It's important information that is collected during diagnosis to know the patient oral hygiene and coffee consuming that affects composite type selection. It is crucial to remember that some drinks, such as coffee and tea, may have an impact on the physical and esthetic properties of resin composites, thereby lowering the restoration's overall quality. The increased intake of acidic aerated beverages by children and young people also presents a risk because the acidity of these beverages may degrade the qualities of resin composites. There is a direct relationship between the acidity of drinks and discoloration of resin composite restorations. Beverages with low pH, such as carbonated soft drinks and energy drinks, can soften and degrade the resin matrix of the composite material. This acidic effect increases surface roughness, making the restoration more susceptible to plaque accumulation and stain adsorption. In addition, degradation of the resin matrix promotes water sorption and allows pigments from colored beverages to penetrate more easily into the material. As a result, the lower the pH of the drink, the greater the risk of surface deterioration and subsequent discoloration of the restoration over time. The aim of this study was to evaluate the color stability of three light-polymerizing resin composites – Clearfil AP-X Esthetics (Kuraray), ELS Xetra (Saremco), and Neo Spectra ST (Dentsply Sirona) – after immersion in commonly consumed beverages (coffee, tea, and water) using spectrophotometric analysis based on the CIE L*a*b* color system.

MATERIAL AND METHODS

Three distinct light-polymerizing composite resins (Shade A2) were employed in this investigation: ELS (Saremco), Neo Spectra ST (Dentsply Sirona), and CLEARFILTM AP-X Esthetics (Kurary dental composites) (Figure 1) and (Table 1). Ninety (n = 90) specimens in total were chosen to be examined in this study, with thirty specimens isolated for each type of composite resin.

As a result, three groups were created from each composite group, each of which contained samples of each substance. To be submerged in several staining solutions (Ebn Amid tea, coffee, and distilled water), each specimen was kept in a closed container. The samples were prepared using a Teflon mold with a diameter of 10 mm and a thickness of 2 mm. The specimen dimensions were selected in accordance with the requirements of ISO 4049 for polymer-based restorative materials. A 2 mm thickness was chosen

Figure 1: Materials used in the study ELS (Saremco), Neo Spectra ST (Dentsply Sirona), and CLEARFIL™ AP-X Esthetics (Kurary dental composites)

to correspond to the recommended incremental thickness for adequate light polymerization of resin composites, while the 10 mm diameter provided a standardized flat surface suitable for reliable spectrophotometric color measurements. These dimensions are also consistent with those used in previous color stability studies, a microscopic glass slide and a clear strip were placed under mold then composite packed in the mold using a burnisher until it reached to the desired thickness, another clear strip and microscopic glass slide were placed above the mold, and slightly pressed against each other to provide a smooth and uniform surface as shown in Figure 2, then light cured according to manufacturer instruction, the light tip diameter of the curing light was 10 mm to cover the whole specimen and the light-curing tip was in contact with microscopic glass slab with perpendicular direction at an angle of 90°.[12] After sample preparation, when the resin composite is against a Mylar matrix, the smoothest surface is achieved without finishing or polishing. This surface has a resin-rich layer and poor mechanical properties. This resin organic binder, which, when in contact with the oral environment, discolors more than the polished surface, should be removed.[13] All prepared samples were stored in distilled water at 37°C for 24 h to allow completion of post-polymerization, initial water sorption, and stress relaxation, as well as to simulate intraoral conditions before baseline color measurements were performed. Furthermore, the samples were immersed in the staining solution, each group of ten samples (n = 10) in each

Table 1: Composition of the evaluated composite materials

Composite material	Manufacturer	Resin matrix composition	Filler type	Filler loading	Photoinitiator system
Clearfil AP-X Esthetics	Kuraray Noritake Dental Inc.	Bis-GMA, TEGDMA	Barium glass, silica microfillers	~85 wt% (≈71 vol%)	Camphorquinone-based system
ELS Xetra	Saremco Dental AG	UDMA-based matrix (TEGDMA-free)	Radiopaque glass fillers, silica	~77–80 wt%	Camphorquinone-based system
Neo Spectra ST	Dentsply Sirona	Bis-GMA-free (UDMA-based)	Pre-polymerized spherical filler (SphereTEC), barium glass	~82 wt% (≈68 vol%)	Camphorquinone-based system

Table 2: Mean and standard deviation of ΔE values

Composite	Immersion medium	ΔE at 10 days (Mean±SD)	ΔE at 20 days (Mean±SD)
ELS Xetra	Coffee	4.90±0.30	6.20±0.40
	Tea	3.80±0.25	4.90±0.35
	Distilled water	2.10±0.15	2.60±0.20
Clearfil	Coffee	4.10±0.20	5.70±0.30
	Tea	3.40±0.20	4.30±0.25
	Distilled water	2.20±0.15	2.80±0.20
Neo spectra	Coffee	4.40±0.25	5.10±0.30
	Tea	3.10±0.20	3.80±0.25
	Distilled water	2.00±0.15	2.50±0.20

SD: Standard deviation

container, closed containers were used, and all the samples were kept in an incubator at 37°C. "The storage solution was renewed daily to prevent bacterial and fungal contamination and to avoid changes in the concentration of the staining medium, thereby ensuring standardized and reproducible conditions throughout the immersion period (ISO, 2019; Guler *et al*., 2005)."

VITA Easyshade compact (Brea, CA, USA, Vident) was used to evaluate the Commission Internationale de l'Éclairage (CIE) L*, a*, and b* color coordinates to measure shade alterations. The data were automatically quantified by the accompanying software, which provided brightness (value, L*) and values for the red-green (a*) and yellow-blue (b*) axes. This makes it possible to compare the colors of the specimens before and after various staining and thermocycling processes mathematically as shown in (Figure 3). The color difference (ΔE) was calculated at the center of each specimen using the color difference (ΔE) formula, which is $\Delta E = (([\Delta L^*]^2 + [\Delta a^*]^2 + [\Delta b^*]^2]½$. Baseline color measurements (T0) were performed after 24 h of storage in distilled water at 37°C and before immersion in the staining solutions. Subsequent color measurements were recorded after 10 days (T1) and 20 days (T2) of immersion. "The average of three readings was calculated for each specimen at each time interval."[14] Before every test, the VITA Easyshade compact was calibrated. Every specimen's (CIE) L*a*b* values were measured, and the light source illumination matched the average daylight (D65).[15]

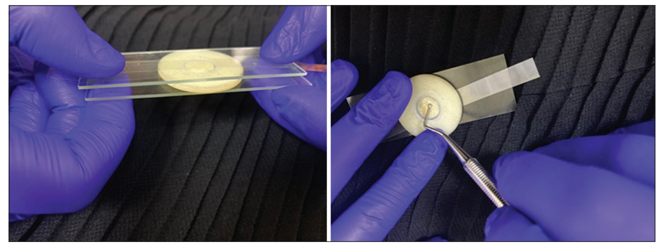


Figure 2: A microscopic glass slide and a clear strip were placed under mold then composite packed in the mold using a burnisher until it reached to the desired thickness, another clear strip and microscopic glass slide were placed above the mold, and slightly pressed against each other to provide a smooth and uniform surface, then light cured according to manufacturer instruction

Figure 3: Spectrophotometer VITA easyshade compact device

RESULTS

The color stability of three composite materials, Clearfil (Kuraray), ELS Xetra, and Neo Spectra (Dentsply), was evaluated in this study following 10- and 20-day intervals of immersion in three distinct media: Coffee, tea, and distilled water. The values of color change (ΔE) were measured with a spectrophotometer. Out of all the composites, Clearfil showed the most color change, especially in coffee. ELS Xetra and Neo Spectra showed the least amount of discoloration overall. In particular, the ΔE values for Clearfil in coffee rose from 4.10 at 10 days to 5.70 at 20 days, staying within the detectable range. ELS Xetra displayed a progressive and clinically noticeable discoloration, with a ΔE increase from 4.90 at 10 days to 6.20 at 20 days. This implies that ELS Xetra is more susceptible to staining, most likely as a result of its increased water sorption and resin matrix properties. In a similar vein, distilled water caused the least amount of discoloration (ΔE = 2.10 and 2.60), indicating baseline material stability in non-staining conditions, but tea immersion produced a moderate color change (ΔE = 3.80 at 10 days and 4.90 at 20 days). Particularly in distilled water, where ΔE values stayed low (2.30 at 10 days, 2.50 at 20 days), Neo Spectra showed the strongest stain resistance as shown in Figure 4. The coffee and tea still showed discoloration, but the ΔE values were lower than those of the other materials. In contrast to tea, which produced a slight increase from 3.10 to 3.80, coffee immersion increased ΔE from 4.40 to 5.10.

Figure 4: Some of the prepared samples after 10 days and 20 days immersion

Overall, these findings support earlier research that noted coffee's dark chromogens and acidic pH as the most severe staining medium. The significance of assessing color stability over clinically relevant durations is shown by the steady rise in ΔE with time observed in all composites and immersion solutions. While the increased discoloration seen with Clearfil and ELS Xetra indicates a more hydrophilic profile or surface roughness, both of which can promote pigment absorption, Neo Spectra's superior performance may be ascribed to its resin composition and filler qualities.

Statistical Analysis

The color shift shown over time in all materials and staining solutions was statistically significant ($P < 0.05$), according to a Wilcoxon signed-rank test as shown in (Table 2).

- Significant differences in ΔE values between the staining solutions for each material were shown by a one-way Analysis of Variance ($P < 0.001$) as shown in (Table 3).
- According to Tukey's *post hoc* analysis
- For every composite, the differences between coffee and distilled water and coffee and tea were statistically significant
- In most situations, there was a noticeable but less noticeable difference between tea and distilled water
- Clearfil and ELS Xetra were more impacted than Neo Spectra, particularly in coffee, according to material comparisons ($P < 0.05$) as shown in (Table 4).

Table 3: Statistical significance of color change over time

Test	Result	*P*-value
Wilcoxon Signed-Rank Test	Significant color change observed	$P<0.05$
One-way Analysis of Variance	Significant differences in ΔE values	$P<0.001$

Table 4: Tukey's post hoc analysis results

Comparison	Result	*P*-value
Coffee versus Tea	Statistically significant	$P<0.05$
Coffee versus Distilled water	Statistically significant	$P<0.05$
Tea versus Distilled water	Significant in most cases, less pronounced	$P<0.05$
ELS Xetra versus Clearfil	More affected than Neo Spectra, especially in coffee	$P<0.05$

National Bureau of Standards (NBS) Unit Conversion and Clinical Relevance

The formula NBS unit = ΔE × 0.92 was used to convert the ΔE values to NBS units. Color changes were categorized into five ranges in this study:

- 1 < ΔE < 2: Only an experienced observer can see the difference
- 0 < ΔE < 1: The difference is undetectable
- 3.5 < ΔE < 5: Clearly visible color changes
- 5 < ΔE: Creates the sense that these are two different hues
- 2 < ΔE < 3.5: An inexperienced viewer also notices the difference as shown in (Table 5).[16]

Consistent with previous research, the color variations seen in this investigation following curing exceeded the threshold of color perceptibility.

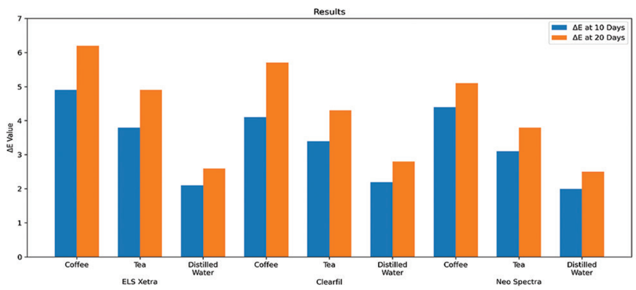
- All components in coffee had NBS values above 12, which, particularly after 20 days, indicated a "very much" noticeable color shift

Table 5: NBS unit conversion

Immersion medium	ΔE range	NBS unit range	Perceptibility level
Coffee	ΔE > 5	NBS > 12	Very much perceptible
Tea	3<ΔE < 5	NBS ~ 3–9	Appreciable to much perceptible
Distilled water	ΔE < 3	NBS < 3	Slight to noticeable changes, clinically acceptable

NBS: National Bureau of Standards

- The color changes caused by tea were "appreciable to much" (NBS range ~3–9)
- NBS units below 3 from distilled water indicated "slight to noticeable" modifications that were clinically acceptable.



DISCUSSION

The results of this investigation shed important light on how three composite materials—Clearfil (Kuraray), ELS Xetra, and Neo Spectra (Dentsply)—hold up over time when exposed to different staining agents. While Neo Spectra displayed the least amount of discoloration overall, Clearfil showed the most color change, especially in coffee, followed by ELS Xetra. In particular, ELS Xetra displayed a ΔE increase from 4.90 to 6.20 while Clearfil's ΔE readings climbed from 4.10 after 10 days to 5.70 at 20 days, both of which indicated clinically noticeable alterations. Consistent with earlier studies,[17,18] these findings imply that ELS Xetra is more susceptible to staining, most likely as a result of increased water sorption and resin matrix properties. Particularly in distilled water, where ΔE values stayed low (2.30 at 10 days, 2.50 at 20 days), Neo Spectra showed exceptional stain resistance. Coffee was found to be the most aggressive staining medium, supporting research that links its strong staining capacity to acidic pH and dark chromogens.[11,19] The assumption that non-pigmented liquids have little effect on composite color stability is further supported by the fact that distilled water produced the least amount of discoloration and immersion in tea produced minor color alterations. Tukey's *post hoc* analysis revealed significant differences between coffee and tea, as well as between coffee and distilled water, for all composites. Statistical analysis revealed significant differences between the staining solutions ($P < 0.001$) and significant changes in color over time ($P < 0.05$). When ΔE values were converted into NBS units, the specimens immersed in coffee exhibited the highest NBS values, indicating a very much perceptible color change, particularly after 20 days of immersion. In contrast, distilled water produced NBS units below 3, which indicate "slight to noticeable" changes, which are typically regarded as clinically acceptable. Numerous factors influence the color stability of resin composites; however, the composition of the resin matrix and the distribution of filler particles are considered the primary determinants of resistance to discoloration when exposed to staining agents, such as tea and coffee.[3,7] Water sorption and stain absorption are significantly influenced by the resin matrix, which is made up of monomers, such as Bis-GMA, UDMA, and TEGDMA. Bis-GMA-based composites typically absorb more water because of their hydroxyl groups, which increases pigment uptake, while UDMA-based composites show better color stability because of lower water sorption.[8,10] In addition, improved polymerization efficiency enhances the color stability of resin composites by reducing the number of unreacted monomers that may absorb pigments from staining agents.[10] In contrast, incomplete polymerization may leave residual monomers within the resin matrix, making the material more susceptible to degradation and discoloration. Furthermore, the filler particle size and distribution also influence stain resistance. Microhybrid composites, which contain larger filler particles, may exhibit increased surface roughness and stain retention, whereas nanocomposites with smaller filler particles produce smoother surfaces that reduce pigment adhesion.[9,12] The type of filler material also affects color stability; contemporary composites commonly incorporate fillers based on barium, zirconium, and silica to improve polishability and reduce stain accumulation.[6] In addition, silane coupling agents enhance the bond between the resin matrix and filler particles. Inadequate silane coupling may create microgaps that allow staining agents to penetrate the composite structure and accelerate discoloration.[7]

Clinically, these mechanisms explain why Neo Spectra ST showed better color stability in this study, probably because of its optimized filler distribution and low-water sorption matrix, while Clearfil and ELS Xetra showed more discoloration, possibly because of rougher filler surfaces that improve pigment absorption or increased hydrophilicity. These findings highlight the importance of appropriate material selection in maintaining the long-term esthetic stability of composite restorations in restorative dentistry.

CONCLUSION

Within the constraints of this in vitro study, all evaluated composite resins demonstrated differing levels of discoloration upon exposure to standard beverages. The most staining happened with coffee, then tea, and distilled water caused the least color change. Neo Spectra ST showed better color stability than the other materials tested, while Clearfil AP-X Esthetics and ELS Xetra were more likely to change color. The results show how important it is to choose the right materials and have good eating habits for patients to keep the long-term esthetic look of composite restorations.

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