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A Novel Method to Distinguish Old Composite from Enamel: Spectrophotometric Validation

Roshni Sharma[1*], Subhra Sahoo[1], Mamta Kaushik[1], Pallavi Reddy[1], Neha Mehra[1] and Uday Kumar[1]

[1]Department of Conservative Dentistry and Endodontics, Army College of Dental Sciences, Secunderabad, India.

Authors' contributions

This work was carried out in collaboration between all authors. Author RS designed the study. Author MK wrote the protocol. Author SS wrote the first draft of the manuscript. Authors MK and NM managed the literature searches. Author SS performed the spectroscopy analysis. Author PR managed the experimental process. Author UK analyzed the statistical part. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To identify a dye for disclosing composite resin restoration margins using tooth shade spectrophotometry.
Materials and Methods:
Study Design: Experimental Study.
Forty sound, non-carious maxillary anterior teeth extracted for periodontal reasons were collected and standard box shaped class V cavities, 5 mm width, 2 mm height and 2 mm depth, were prepared and restored with composite resin. The samples were stored for 2 months in distilled water at 37℃ and thermocycled for simulating agein g process (5℃-55℃/5000 cycles). Samples were then assigned into four groups according to the dyes used for staining: Coffee (5%), Carmoisine (0.1%), Erythrosine (1%) and Methylene blue (1%). A tooth shade spectrophotometer was used to assess the change in shade of enamel and composite resin before and after staining with four different dyes. The data was analyzed using one-way analysis of variance and Post Hoc LSD tests.

**Corresponding author: E-mail: roshni3077@gmail.com;*

Results: The results of spectrophotometric analysis of enamel and composite staining showed that Methylene blue caused maximum composite staining ($p<0.05$). Erythrosine also showed a significant change in shade of composite, greater than enamel due to hydrophobic interaction between the resin and dye ($p<0.05$). The two hydrophobic food stains Coffee and Carmoisine showed no significant change in colour of composite and could not distinguish the boundary between composite resin and tooth enamel ($p>0.05$).
Conclusion: The exposure of specimens to colored solutions resulted in significant colour alteration. Composite resin is more stainable by hydrophobic dyes compared to tooth enamel.

Keywords: Composite; disclosing; dye; enamel; hydrophobic; spectrophotometer.

1. INTRODUCTION

Composite restorations are among the most frequently used esthetic restorative materials in dental practice. Demand for composite resins has grown due to their ability of bonding to enamel and dentin, their resemblance to teeth, and good mechanical properties [1]. Composite discoloration, recurrent caries, and microleakage causing sensitivity are generally the most common reasons for restoration replacement. Removal of such restorations can be time consuming, problematic and stressful for the dental practitioner. Also, in patients undergoing fixed orthodontic treatment for malocclusions the composite which remains bonded to the tooth enamel after debonding of brackets must be removed [2]. Hence, a composite disclosing dye would help the practitioner to differentiate the boundary of composite with the tooth and remove such restorations without damaging the adjacent healthy tooth structure.

Discoloration in composite resins can be due to intrinsic or extrinsic factors [3]. Extrinsic discoloration is a result of the interaction between coloring agents in beverages with the composite material. Extrinsic staining occurs due to smoking, dietary intake of tannin-rich foods (e.g. tea, coffee and red wine) which can be attributed to presence of high content of polyphenols providing color and presence of carbon-rich layer on outer enamel surface. These polyphenols may act by two methods: 1) Directly, by adhering to tooth enamel surface; 2) Indirectly by interacting with salivary proteins [4,5]. Discoloration of resin-based composites by colored solutions is a common problem [6]. In this study we used instrumental shade analysis as a method to determine the staining properties of enamel and composites based on their hydrophobicity/hydrophilicity. The aim of this study is to identify a dye for disclosing composite resin using tooth shade spectrophotometry.

2. MATERIALS AND METHODS

2.1 Preparation of Chemicals

Coffee (5%), Carmoisine (0.1%), Erythrosine (1%), and Methylene Blue (1%) solutions were prepared to perform the staining experiments. Coffee Solution was prepared by stirring 5.0 g of its powder in 100 ml deionized water. Carmoisine solution was prepared by dissolving 0.1 g of its powder per 100 ml of ethanol and acetone. Erythrosine solution was prepared by dissolving 1.0 g of its powder in 100 ml of deionized water while Methylene Blue solution was prepared by dissolving 1.0 g of its powder per 100 ml deionized water.

2.2 Tooth Collection and Preparation

Forty maxillary anterior teeth, extracted for periodontal reasons were collected from the Department of Oral Surgery, Army College of Dental Sciences (sample size was statistically determined from data obtained from a previous pilot study). Institutional ethical clearance for the study was obtained and the Helsinki declaration for the use of human teeth was followed. Teeth selected were free of caries, stains, cracks, demineralization, severe pitting or atypical intrinsic stains. After scaling, teeth were stored in distilled water for 2 weeks. Forty samples were then divided into four groups (n=10) based on the type of dye solution used for staining as exhibited in Table 1. Standard box shaped class V cavities were prepared with a 5 mm mesio-distal width, 2 mm inciso-cervical height and 2 mm depth in all the samples.

Table 1. Test groups and dyes

Groups (n=10)	Dyes
Group 1	Coffee Solution (5%)
Group 2	Carmoisine Solution (0.1%)
Group 3	Erythrosine Solution (1%)
Group 4	Methylene Blue Solution (1%)

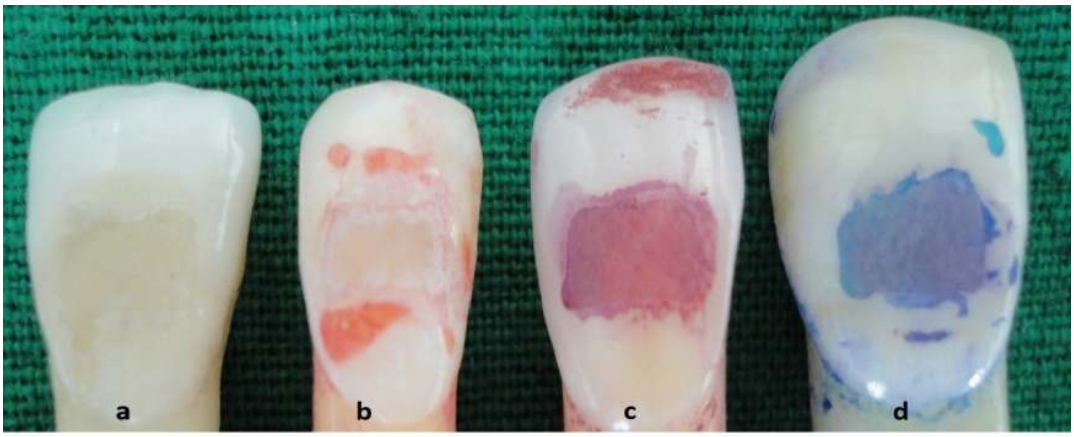


Fig. 1. The digital photograph showing change in colour of specimens after staining with four dye solutions a) Coffee group b) Carmoisine group c) Erythrosine group d) Methylene blue group

The cavities were randomly restored following the manufacturer's instructions. The cavity preparations were etched for 15 s using 37% phosphoric acid (N Etch, Ivoclar vivadent, Asia), then washed for 15 s and gently air-dried to prevent excessive dentin drying. The adhesive system Tetric N-Bond (Ivoclar vivadent, Asia) was applied using the total-etch technique in two consecutive coats, lightly air-dried for 10 s, and light polymerized at 1000 mW/cm^2 for 40 seconds, using a halogen curing unit. The A2 shade of nanohybrid resin composite (Tetric® N-Ceram, Ivoclar vivadent, Asia) which is the most commonly used shade in our dental practice was used for restoration of cavities. The specimens were then subjected to storage in distilled water at 37℃ for 2 months and thermocycled for 5,000 cycles in water, with bath times of 30 s in 5℃ and 55℃, with transfer time between one bath to other of 2 s to simulate ageing process.

2.3 Staining Procedure

For baseline shade measurements, the specimens were blot dried and measurements were taken using tooth shade Spectrophotometer (SpectroShade Micro MHT, Verona, Italy) for both enamel and composite resin surface. Specimens were kept hydrated in distilled water between shade measurements and were handled carefully using clean forceps. The shade readings were taken for each specimen before and after the staining procedure using percentile units of Munsell's color system (hue, chroma and value/lightness) which is the most commonly used color system in dental practice. Specimens were then immersed in four dye solutions for 30 seconds for staining (Fig. 1 above). After staining, specimens were rinsed under running water for 5 minutes. Samples were blot dried and shade was again measured for enamel and composite resin surfaces after the staining procedure. Specimens were then cleaned with a polishing brush and a paste for 5 minutes. This completely removed the stain from enamel but left the composite stain unaltered.

2.4 Statistical Analysis

Statistical analysis was performed using One-way analysis of variance (ANOVA) and Oneway analysis for change in hue (ΔH), chroma (ΔC) and value (ΔL) of enamel (E) and composite (C) before and after staining at a significance level of $p<0.05$. Post Hoc LSD test was used to see pair wise significance. All the analysis was done using SPSS version 18.

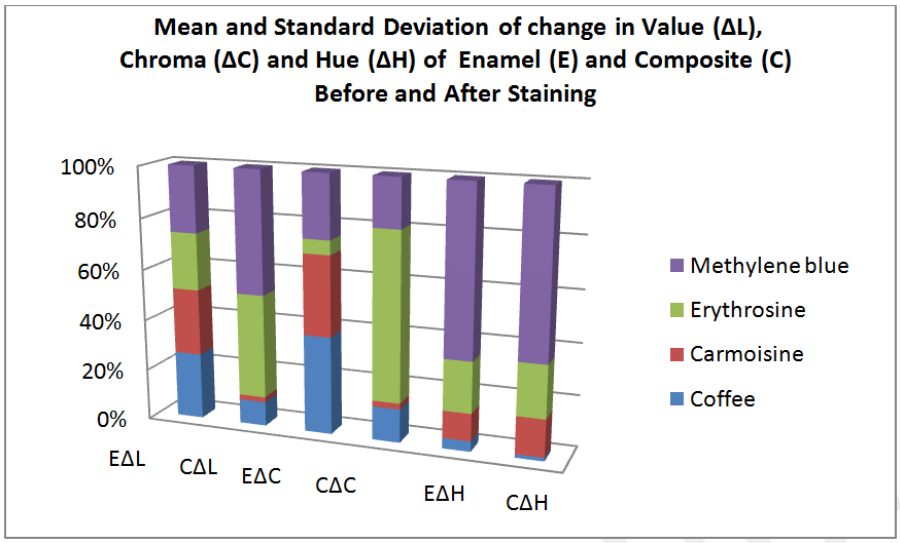
3. RESULTS

The mean values and standard deviations of change in hue, chroma and value of enamel and composite before and after staining are exhibited in Table 2 and Graph 1. The change in shade parameters i.e change in hue, chroma and value of enamel and composite resin surfaces were recorded and compared using tooth shade dental Spectrophotometer for all the samples before and after staining (Figs. 2-5). One-way analysis of variance (ANOVA) was applied to compare mean difference between four dyes. The pair wise significance was analysed using Post Hoc LSD test.

Table 2. Statistical analysis- mean and standard deviation of change in Value (ΔL), Chroma (ΔC) and Hue (ΔH) of Enamel (E) and Composite (C) before and after staining using ANOVA

Group	EΔL	EΔC	EΔH	CΔL	CΔC	CΔH
Coffee	-67.19±6.64^{a}	-13.40±7.30^{a}	-11.04±7.37^{a}	-5.83±6.16^{a}	-5.01±3.72^{a}	-4.32±5.58^{a}
Carmoisine	-66.65±7.68^{ab}	-11.04±6.38^{ab}	-28.84±10.96^{ab}	-1.24±4.03^{ab}	-0.89±6.10^{ab}	-45.50±13.98^{b}
Erythrosine	-57.78±12.70^{c}	-1.95±8.53^{c}	-53.69±17.38^{bc}	-24.86±5.89^{c}	-25.13±5.59^{c}	-63.72±7.83^{bc}
Methylene blue	-67.13±6.91^{ad}	-8.72±9.65^{acd}	-177.26±86.00^{d}	-29.56±9.98^{cd}	-7.27±8.98^{d}	-198.96±45.86^{d}

**a, b, c and d- Different superscripts are statistically significant at p<0.05 using Least Significant Difference (LSD) Test*



Graph 1. Graphical representation of mean and standard deviation of change in Value (ΔL), Chroma (ΔC) and Hue (ΔH) of Enamel (E) and Composite (C) before and after staining

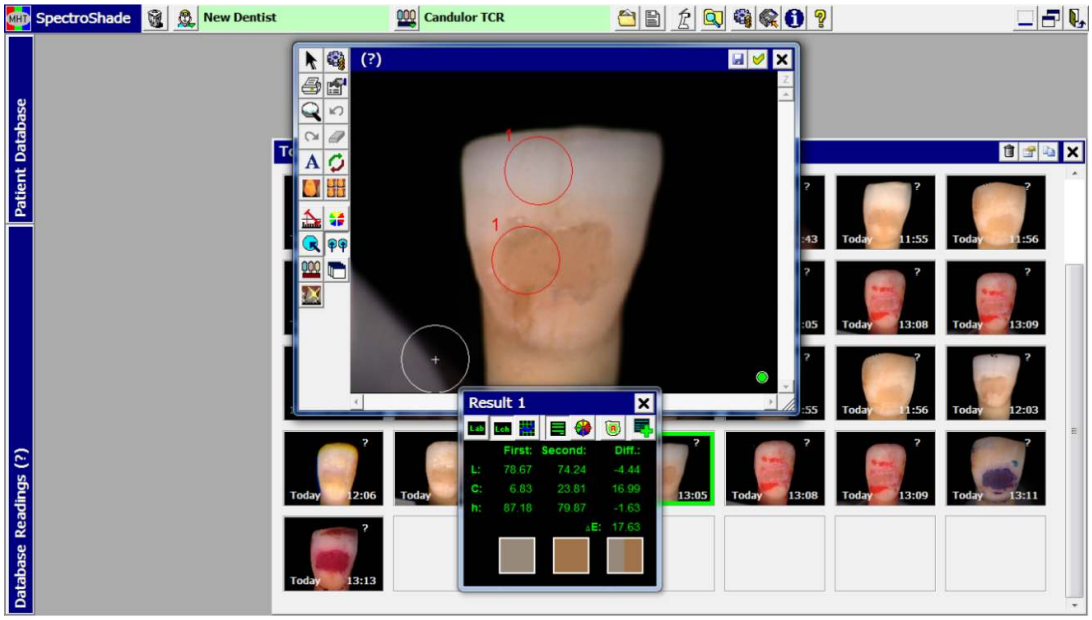


Fig. 2. Spectrophotometric image of teeth stained with Coffee solution in SpectroShade Software

After staining, Coffee showed slight change in value and chroma of both enamel and composite but no significant change in hue i.e. Coffee had no significant effect on any shade parameter ($p>0.05$). Carmoisine showed significant change in hue of both enamel and composite ($p<0.05$). Erythrosine showed change in both lightness (value) and chroma of composite and significant change in hue of both composite and enamel ($p<0.05$). Methylene blue showed the most significant change in hue of enamel and composite ($p<0.05$) and also significant change in value and chroma of composite ($p<0.05$). As hue distinguishes between different families of color, more hue results in composite visibility. The most significant change in hue of composite after staining was seen in the Methylene blue group followed by Erythrosine, Carmoisine and Coffee groups.

Fig. 3. Spectrophotometric image of teeth stained with carmoisine solution

Fig. 4. Spectrophotometric image of teeth stained with erythrosine solution

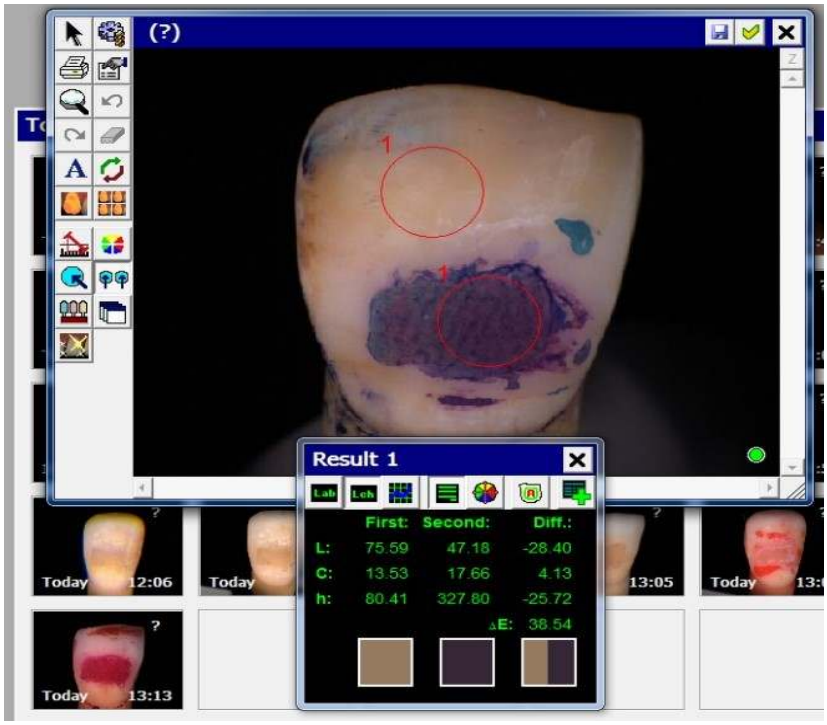


Fig. 5. Spectrophotometric image of teeth stained with methylene blue solution

4. DISCUSSION

In this study the effects of different dye solutions on the change in shade of tooth enamel and composite resin surfaces were compared. As discussed earlier there can be various reasons for extrinsic tooth staining but the most important role is played by the carbon-rich layer covering the outer enamel surface which makes it hydrophobic in nature. Composite resin stains more than the tooth enamel with hydrophobic dyes indicating that composite is more hydrophobic than outer enamel [1]. This information was used to identify a disclosing dye for composite resin which could make the task of composite removal easier for the dental practitioner.

Tetric N-Ceram is a light-curing, radiopaque nano-hybrid composite based on nano-optimized technology for direct restorative procedures which can be universally used for restoration of teeth in both anterior and posterior regions. Its nano-optimized filler technology is responsible for natural esthetic results. The samples were stored for 2 months in distilled water at 37℃ and thermocycled (5℃-55℃/5000 cycles) to simulate ageing process as in most clinical situations during repairing and replacing composite restorations there is a need for removal of old composite resin [7].

A basic understanding of the elements of tooth color is important in restorative dentistry [8]. Teeth are typically composed of a number of colors and a gradation of color occurs in an individual tooth from the gingival margin to the incisal edge of the tooth. Color can be described according to the Munsell terms of hue, value and chroma. Hue is the descriptive term to enable one to distinguish between different families of color, for example reds, blues and greens. Value is the relative lightness and darkness of a colour on a scale from black to white. Chroma is the degree of colour saturation and describes the strength of a color as it changes, for example, from pink to crimson [1,9,10].

The subjective interpretation of tooth color by the operator is highly dependent on the individual and can be inaccurate. In contrast, instrument colour measurement has the potential to eliminate the subjective variables of shade selection [11]. A number of color measuring instruments are commercially available such as ShadeVision (X-Rite, Grand Rapids, MI, USA), which is a colorimeter; Easyshade (Vita Zahnfabrik, Bad Sackingen, Germany), which is

a spectrophotometer that does not provide images; however, SpectroShade Micro (MHT, Verona, Italy) and Crystaleye, are spectrophotometers which also provide images [12]. Hence, in this study SpectroShade Micro has been used due to its precise measurement and the objective description of the tooth's color, natural or artificial, in every light condition.

Spectrophotometers, generally, can provide more systematic and precise measurements than colorimeters because of their ability to measure the amount of light reflected from objects throughout the visible spectra range. A color-measuring instrument with computerized color analysis allows for standardized and accurate color matching compared with conventional techniques.

Caffeine present in coffee is an FDA approved psychoactive drug commonly used in the food industry contains white crystalline purine, a methylxanthine alkaloid which makes it hydrophobic in nature. Coffee was chosen as a dye testing substance because it is frequently consumed [13,14]. Coffee exhibits a strong potential for staining both tooth structure and resinous materials. The compatibility between the brown dye of the coffee and the resin polymer chain has been suggested, facilitating the adsorption and penetration of the dye in the resin. The specimens immersed in coffee exhibited a yellow appearance, besides reduced lightness [15,16].

Carmoisine is an FDA approved synthetic red food dye from the azo dye group and is used in the food and cosmetic industries. Erythrosine is an FDA approved organo-iodine compound, specifically a derivative of fluorone. It is a cherry-pink synthetic stain primarily used for food coloring. Other uses of erythrosine include printing inks, biological stain, dental plaque disclosing agent, radiopaque medium and sensitizer for orthochromatic photographic films. Methylene blue is an FDA approved basic dye that contains cationic nitrogen molecules. In dentistry methylene blue is used to identify cracks, microleakage or accumulation of plaque.

Abdallah and Nathan used X-ray photoelectron spectroscopy (XPS) to determine the elemental composition of dental enamel and composite resin surfaces which revealed that both enamel and composite resin contain high amounts of hydrocarbons. They found that both enamel and composite resins are stainable with hydrophobic dyes with composite being more stainable than enamel [1]. In this study the results of spectrophotometric analysis of enamel and composite staining showed that composite was best stained by the cationic methylene blue stain. Erythrosine also showed significant change in hue of composite greater than enamel due to hydrophobic interaction between the resin and dye. The two FDA approved hydrophobic food stains coffee and carmoisine also induced some changes in colour of composite but not sufficient enough to distinguish the boundary between composite resin and tooth enamel.

The detection of composite resin is usually done by visual inspection under conventional illumination and tactile sensation but greatly depends on the experience and skills of the examiner [17]. Ultraviolet light (UV) light in range of 265-380 nm is one of the most useful wavelength for detection of resins but it is very harmful for human body [17,18]. Also, alternative light source and quantitative light-induced fluoresce (QLF) techniques have also been used to detect the composite resin. But the drawback of these methods is that the fluorescence emission is better visualized in a dark environment which is impractical in the dental office [19,20]. Even though the visual inspection revealed similar results, the subjective methods are highly operator dependent and can lead to inaccuracy, hence, spectrophotometric method has been used in this study for objective description of color change in composite restorations.

In this study it was found that after cleaning the samples, the staining of enamel was reversible but staining of composite was irreversible with a 30 second application time. In previous studies different dyes such as ink dye and brilliant green have been used for easy detection of composite but most of them are not FDA approved and are toxic [21,22]. Other studies suggested that tea [23], cola and red wine [24] etc. also stains the composite resin [13].

Orthodontic composites also show discoloration from staining beverages over a long period of time. In esthetically critical areas, discoloration of such adhesive materials for fixed orthodontic treatment can cause patient dissatisfaction [25]. Also, composite staining dyes can be a useful technique of orthodontic bracket debonding procedures [26].

Based on our understanding of the interactions between enamel and composite resins and stains, we developed a staining protocol that

would allow dental practitioners using dental spectrophotometer to easily distinguish the boundaries between composite resins and tooth enamel. Further studies are required to evaluate the effectiveness of these dyes to stain dentin as esthetic restorative procedures involve restoration and re-restoration of enamel and dentin both.

5. CONCLUSION

Under the limitations of the study it can be concluded that a composite disclosing dye would help the dental practitioner in easy and quick detection and removal of composite without damaging the natural tooth structure. Methylene blue can be used as a disclosing dye for composite resin for better visibility of boundaries between composite resin and dental enamel. This study concentrated on the disclosure of enamel from composite resins, further research should be performed to find a disclosing dye for dentin.

CONSENT

It is not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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