

AT WHAT DEPTH STAINING OF COMPOSITE CAN BE REVERSED?

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ABSTRACT

BACKGROUND: Since the introduction of resin composites, the staining of composite restoration has been a common concern. Most studies on resin-based composite restorations have focused on removing surface stains, with limited attention to the extent of bleaching achievable within the material's depth.

AIM: This study aims to evaluate the in-depth effect of bleaching agent on previously pigmented composite

MATERIAL AND METHODS: A submicrohybrid resin composite (BRILLIANT EverGlow) were used to fabricate the test specimens of 8mm x 2mm diameter and width respectively. The samples were immersed in a coffee-based staining solution for 15 days to induce extrinsic discoloration. Then the sample were stored in physiologic solution for 12 days. Following the staining protocol, a 35% hydrogen peroxide bleaching agent (SDI Pola Office) will be applied over the samples for 10 days for 8 hours every day. Assessment of pigment penetration, amount of discoloration and the depth of the bleaching agent penetration were done using a flatbed computerized scanner. On each scanned image, the centre of the circular surface was identified. Colour measurements were taken at 9 points, starting at 0.1 mm from outer surface and extending to a depth of 3.0 mm. The CIELab system was used to quantify colours. Whiteness value was calculated using CIELab measurements.

RESULT: Results of the study showed statistically significant difference among the control, stained and whitening group. Discoloration by coffee stain was seen upto level of 2.5mm and the bleaching significantly improved whiteness, showing highest recovery superficially up to 0.4mm and progressively lower recovery was seen in depth.

CONCLUSION: Coffee staining affected composite resin at varying depths, potentially compromising esthetic longevity. Whitening effectively restored the initial whiteness, with greater efficacy in superficial than deeper layers.

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INTRODUCTION

With the growing emphasis on esthetic dentistry, patients increasingly demand tooth-colored restorative materials that closely mimic the natural appearance of teeth. As a result, resin-based composites have become widely used in restorative procedures. However, discoloration of these restorations - either intrinsic, due to material degradation and aging, or extrinsic, caused by

dietary chromogens, smoking, and oral hygiene habits remains one of the primary reasons for their replacement after clinical service in the oral environment.^[1,2,3]

Once a restoration becomes discolored, there are a few ways to bring back its original color. Polishing is usually the preferred option because it is quick and conservative. However, polishing does not always work, especially when stains have penetrated deep into the composite material. In

those cases, removing enough material to correct the color would be excessive in order to achieve an acceptable appearance.^[3,4]

However, as replacement is not always the most appropriate option, bleaching has emerged as a convenient, rapid, and cost-effective strategy for the management of discoloration, particularly when replacement of existing restorations is undesirable. Several authors suggest that bleaching agents mainly remove superficial stains rather than producing true intrinsic whitening of restorative materials. Various previous studies have evaluated the effect of whitening agent like pola office and reported its effectiveness in restoring the whiteness of discolored composite.^[5,6,7]

The effectiveness of bleaching on composite restorations depends on the material's composition, filler content, and resin matrix characteristics. Brilliant EverGlow™ (Coltene/Whaledent® AG, Altstätten, Switzerland) is a universal hybrid composite containing submicron barium glass fillers and pre-polymerized fillers. There are limited studies on its discoloration and effect of bleaching agent on its whitening. Thus, this study was conducted to evaluate the depth up to which coffee can cause staining in Brilliant Everglow composite and effect of Bleaching agent in causing intrinsic whitening.^[8]

MATERIAL AND METHODS:

The study protocol was approved by the Ethics Committee of Vyas dental college and Hospital, Jodhpur.

A commercially available submicron hybrid composite (Brilliant EverGlow™, Coltene/Whaledent® AG, Altstätten, Switzerland) was utilised in this study. (Table 1)

Composite resin	Sha de	Filler technology	Compos ition	Fille r Volu me (%)
Brilliant EverGlow™ (Coltene/Whaledent® AG, Altstätten, Switzerland)	A2	Submicron barium glass fillers, and pre-polymerised filler (Nano-hybrid)	Bis-GMA, TEGDM A, bis-EMA, pre-polymerised filler containing dental glass and nano-silica aggregated and non-aggregated	64

			ed Barium glass (20-1500nm)	
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Table 1: Characteristics of nano-hybrid composite resin used in test.

Specimen Preparation:

Twenty resin composite discs (Brilliant EverGlow) with dimensions similar to the dimension of composite syringe i.e. 8.4 mm in diameter were fabricated directly from the composite syringe. To obtain the required thickness of 2 mm, composite material was extruded from the syringe and measured using two glass slabs, each 1 mm thick, placed adjacent to the syringe tip. The extruded composite was then sectioned using a BP blade. The composite discs were positioned between two glass slabs and light-cured for 20 seconds each from both sides. After curing, any irregularities at the composite disc edges were removed using abrasive discs. Two layers of transparent nail paint were applied to both flat surfaces of each disc, leaving only the lateral surface exposed. This procedure isolated the upper and lower surfaces, ensuring that the pigmenting agent and subsequent bleaching gel penetrated exclusively through the lateral surface. The specimens were then stored for 15 days in a physiological solution at 37 °C before staining procedure.

Specimen analysis:

Specimens were analyzed using a flatbed computerized scanner (Epson Perfection V850Pro) with 1,200 DPI resolution. On each scanned image, the center of the circular surface was identified. By then, tracing a line passing through the center, 10 square-shaped points with a size of 25 pixels (5 × 5) were identified. First at 0.1 mm from the outer perimeter, the following at 0.2 mm, 0.3 mm, 0.4 mm, 0.5 mm, 1.0 mm, 1.5 mm, 2.0 mm, 2.5 mm, 3.0 mm from the outer perimeter (fig. 1). The color CIELab system (Commission Internationale de l'Eclairage) was used to quantify colors. Different color parameters were measured for each recorded area. The average values of L* (lightness), a* (redness) and b* (yellowness) were recorded and then the W (Whiteness index) was calculated using following formula and the readings were recorded at each marked point.^[1]

$$W = 100 - \left[(a^*)^2 + (b^*)^2 + (100 - L^*)^2 \right]^{\frac{1}{2}}$$

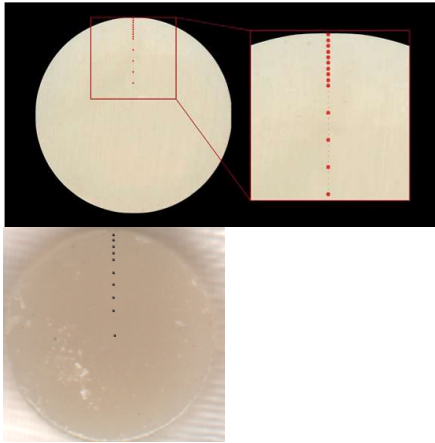


Figure 1: Specimen with points where colour detection was made

Staining procedure:

The specimens were subjected to the pigment treatment with coffee solution using 1.6 g of coffee (Nescafé Classic Nestlé, Vevey, Switzerland) in 100 ml of boiling water for 15 days, and the coffee solution was replenished every day. At the end of staining treatment, samples were extracted from the solution and washed under tap water for 1 minute. The lateral surfaces of the specimens were cleaned with toothbrush and toothpaste (Colgate) for 30 seconds. Subsequently, the specimens were analyzed using a flatbed computerized scanner with 1,200 DPI resolution, and whiteness index based on CIELab measurements was calculated at every marked point. The specimens were immersed in a physiological solution and stored in physiologic saline solution at 37°C for 15 days as done before.

Whitening procedure:

The specimens were subjected to the whitening treatment with bleaching agent Pola Office that uses 37.5% hydrogen peroxide gel, for duration of 10 days for 8 hours every day (fig. 2). During the period of the whitening treatment, the specimens were completely covered with the whitening gel and kept in an oven at 37°C with 100% humidity. After 8 hours of treatment, the specimens were rinsed under running water and placed in a physiological solution for 10 days. Again, the specimens were analyzed using a flatbed computerized scanner with 1,200 DPI resolution. And whiteness index based on CIELab measurements was calculated at every marked point.

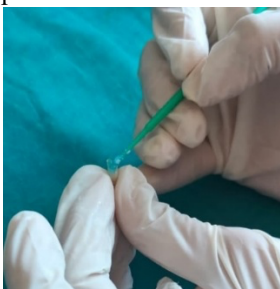


Figure 2: application of bleaching agent

RESULTS:

The Whiteness Index (W) values showed a clear effect of staining and subsequent bleaching across different depths. Staining reduced the W values at all depths, with the largest decrease observed at the surface (0.1 mm, $\Delta = -7.78$) and progressively smaller changes at deeper levels, indicating that staining penetration decreased with depth. [Table 2, chart1]

Statistical Comparison	Mean difference	Standard deviation	p-value (paired t-test)
Without staining vs. With staining	-3.36	2.74	<0.001
With staining vs. After bleaching	+2.04	2.53	<0.001
Without staining vs. After Bleaching	-0.45	0.95	0.161

Table 2: Statistical comparison of the groups

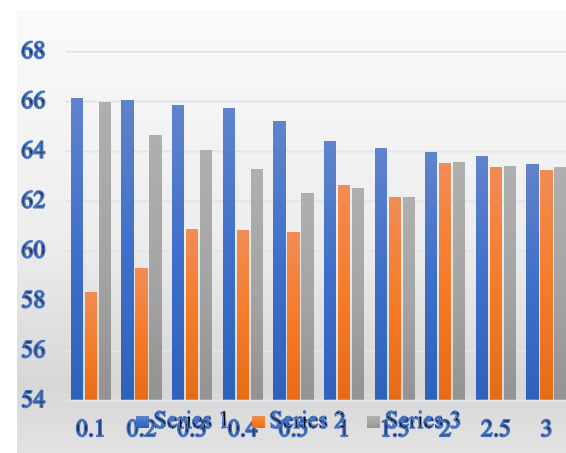


Chart 1: Bar chart of overall mean color change imparted by staining and whitening treatment.

Bleaching effectively increased W values at superficial depths, with recovery percentages ranging from 97.9% - 62.9% (0.1-0.4mm) to 50.4% - 9.1% (0.5-1.5mm) and 6.7% in deep region (2-3mm), showing that surface regions responded better to bleaching than deeper layers. Paired t-tests and post hoc demonstrated that staining significantly reduced whiteness compared to the unstained condition (mean difference = -3.36, $p < 0.001$), confirming the visible effect of staining. Bleaching significantly increased whiteness relative to the stained state (mean difference = +2.04, $p < 0.001$), indicating effective reversal of discoloration. [Table 3]

Measure	Without	With Stain	After Bleach	*p* value
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depth (mm)	Staining	ng	ng	
0.1	66.14 (1.7) ^a	58.36 (0.9) ^b	65.98 (0.9) ^a	< 0.0001
0.2	66.05 (1.4) ^a	59.32 (0.7) ^b	64.63 (0.7) ^a	< 0.0001
0.3	65.86 (1.1) ^a	60.90 (0.6) ^b	64.02 (0.6) ^a	< 0.0001
0.4	65.71 (0.9) ^a	60.83 (0.5) ^b	63.29 (0.5) ^a	< 0.0001
0.5	65.20 (0.9) ^a	60.77 (0.5) ^b	62.33 (0.5) ^c	< 0.0001
1.0	64.41 (0.6) ^a	62.66 (0.3) ^b	62.50 (0.3) ^{bc}	< 0.0001
1.5	64.12 (0.6) ^a	62.16 (0.3) ^b	62.17 (0.3) ^{bc}	< 0.0001
2.0	63.97 (0.5) ^a	63.52 (0.3) ^b	63.55 (0.3) ^{bc}	< 0.0001
2.5	63.80 (0.6) ^a	63.36 (0.3) ^b	63.40 (0.3) ^{bc}	0.0042
3.0	63.49 (0.6) ^a	63.25 (0.3) ^a	63.37 (0.3) ^a	0.1797

Table 3: Composite Color Changes imparted by staining and whitening treatment.

However, the comparison between the unstained and bleached states showed no significant difference (mean difference = -0.45, $p = 0.161$), suggesting that bleaching was generally able to restore the original whiteness over the surface layers.

Depth-wise analysis highlighted that staining predominantly affected the surface (0.1–0.4 mm), with ΔW values of -7.78 to -4.96, while shallow regions (0.5–1.5 mm) experienced moderate staining (-4.88 to -1.75) and deeper regions (2.0–4.0 mm) were minimally affected (-0.45 to -0.24). [Table 4]

Depth range	Maximum staining effect	Bleaching recovery (%)
Surface (0.1 – 0.4mm)	-7.78 to -4.96	62.9% - 97.9%
Shallow (0.5 – 1.5mm)	-4.88 to -1.75	50.4% - 9.1%
Deep (2.0 – 4.0mm)	-0.45 to 0.24	6.7% – 50.0%

Table 4: Depth wise analysis of staining penetration and bleaching efficacy

Bleaching efficacy followed the inverse trend, with the highest recovery observed in surface layers (62.9% - 97.9%) and the lowest in deep layers (6.7%–50.0%). These results indicate that both staining penetration and bleaching effectiveness are depth-dependent, with surface layers being most susceptible to staining and most responsive to bleaching treatments. Whiteness at the depth of 3 mm is similar in all the group as there is no penetration of staining and bleaching agent.

DISCUSSION:

Several authors have suggested that the mechanism and extent of colour change produced by bleaching differ considerably between natural teeth and composite resin restorations. In natural teeth, bleaching agents can diffuse through the enamel and dentin and oxidize chromogenic molecules, resulting in true internal whitening.^[2,9,10] In contrast, composite resins do not possess the same enamel–dentin structure or permeability, consequently, the colour change observed in composite restorations following bleaching is thought to be predominantly the result of removal or oxidation of superficial stains, rather than from a true intrinsic alteration of the composite material itself [Poggio C et al. (2012)]^[10]. This study evaluated the depth of penetration of the bleaching agent (Pola Office) into discoloured composite resin and determined its ability to induce intrinsic whitening at different depths within the restorative material.^[17]

The specimens stored in coffee showed a significant greater discoloration than the control group. Pigmentation was maintained down to a depth level of 2.5 mm. This highlights that the pigmented powder of coffee can act not only on the surface but also in the deeper layers of the specimens to cause discolouration^[11]. The results of the study showed the ability of the bleaching gel to restore the color of the resin almost to its original one, down to a depth of 0.5 mm. The whitening effect was still detected up to the depth of 1.5 mm. Durner J et al. in 2011 speculate that whitening products may induce oxidative cleavage of material's 3-dimensional polymer network. This process may facilitate the penetration of bleaching molecules into the material's internal structure, offering a possible explanation for the findings of the present study^[1,12].

Thickett E et al. in (2009), Goldberg M et al. in (2010), Lago M et al. in (2017) speculated that hydrogen peroxide undergoes decomposition to generate reactive oxygen species (ROS), which possess strong oxidative properties. These highly reactive species interact with chromophoric molecules responsible for tooth or material discoloration.^[13,14,15] ROS oxidize the conjugated double bonds and other chromophoric molecules, disrupting their molecular configuration. This process leads to fragmentation and alteration of these molecules, thereby reducing their ability to absorb visible light and ultimately resulting in a lighter and less intensely coloured appearance.^[3,6,18,21]

Brilliant EverGlow (Coltene/Whaledent® AG, Altstätten, Switzerland) is a submicro-hybrid composite that contains a combination of small and large filler particles.^[8] Although many spaces are filled, some voids may remain, which could contribute to discoloration. These voids may also increase the permeability of material, allowing

bleaching agents to penetrate and travel through composite. Hydrogen peroxide may interact with the three-dimensional polymer network of composite resins, potentially promoting the release of residual monomers such as triethylene glycol dimethacrylate (TEGDMA). Composites containing a higher proportion of hydrophilic resin components, such as TEGDMA, may permit greater diffusion of bleaching molecules into the resin matrix.

However, the present study did not reveal any statistically significant decrease in discoloration beyond a depth of 0.5 mm. This behaviour may be attributed to its distinctive resin–filler architecture, which could restrict the diffusion of bleaching agents and the reactive oxygen species (ROS).^[16,18] As the bleaching agents penetrate deeper into the composite, they must traverse multiple structural barriers, including filler particles, cross-linked polymer chains, and the resin–filler coupling interface. Consequently, increasing material depth may progressively limit the diffusion and activity of bleaching molecules and ROS, thereby reducing their ability to interact with and oxidize chromogenic molecules located deeper within the composite. The findings of the present study are consistent with those reported by Giachetti et al. (2024), who evaluated the whitening efficacy of Opalescence PF 10% gel on Filtek Supreme XTE (3M ESPE) following coffee staining and observed a statistically significant reduction in discoloration only up to a depth of 0.5 mm.^[1] This suggests the inability of bleaching agent to restore the original colour of composite at a depth greater than 0.5 mm. Future research should focus on developing composite materials less susceptible to discoloration, as well as whitening agents with improved penetration into the polymeric resin matrix to restore the material's original shade.

CONCLUSION:

Within the limitations of this study, it was concluded that, coffee stains have the potential to infiltrate the deeper layers of composite resin restorations, affecting their esthetic longevity. The action of the whitening gel is effective in restoring the white value close to the initial one, in the more superficial layers than in depth.

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