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# Tooth Bleaching Effects on Colour Matching of Single-Shade Composite Restorations

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## ABSTRACT

**Background:** Tooth bleaching is a common cosmetic procedure, but it can result in colour mismatches with existing resin composite restorations. However, single-shade composite resins are designed to adapt to the colour of bleached teeth, potentially eliminating the need to replace restorations.

**Objective:** To evaluate the effect of tooth bleaching on colour matching of single-shade resin composite restorations using instrumental and visual assessments.

**Methods:** Round restoration preparations on the buccal and palatal surfaces of intact molars were restored with Charisma Diamond One or Palfique Omnichroma composite resins. Colour measurements were taken using a cell phone and image-processing software before and after restoration and again after 3 applications of a 35% hydrogen peroxide bleaching agent. Colour changes were calculated using whiteness ($WI_D$) and CIELAB colour difference ($\Delta E_{00}$) indexes. Visual assessments of colour match were also conducted by evaluators.

**Results:** Both restorations and enamel exhibited comparable $WI_D$ values after bleaching, and no significant changes in $\Delta E_{00}$ values were observed. However, evaluators assigned better colour matches to unbleached restorations.

**Conclusion:** Instrumental colour measurements indicated that tooth bleaching did not significantly affect the colour match of single-shade resin composite restorations. However, visual assessments revealed poorer colour matching after bleaching.

## Introduction

Tooth bleaching is a popular cosmetic procedure used to improve the appearance of discoloured teeth and enhance smile esthetics. The mechanism of action is not fully understood, but bleaching agents work primarily by increasing enamel opacity and oxidizing phosphoproteins in dentin, which are responsible for tooth discolouration.[1–3] Tooth bleaching can be performed in a dental office using high-concentration hydrogen peroxide-based solutions or at home using trays containing carbamide or hydrogen peroxide at lower concentrations. Clinical trials have shown both techniques to be effective, either alone or in combination.[4–7]

A significant consideration in tooth-bleaching protocols is the presence of restorations in esthetic areas. Dental bleaching often leads to colour discrepancies between restorations and surrounding tooth structure, as peroxides have a more pronounced bleaching effect on natural tooth tissues than on resin composites.[8–11] Consequently, patients may need to replace anterior resin restorations after tooth bleaching.

Colour mismatches caused by tooth bleaching have been evaluated mainly for composite systems based on varying shades and translucency levels.[12] More recently, single-shade composites have been introduced to simplify restorative procedures by eliminating the need to determine composite shades for esthetic restorations. These materials are designed to adapt their colour to match the surrounding substrate.[13–18] Their ability to adjust colour is primarily attributed to the high translucency achieved after composite polymerization, which creates a mirror effect of the underlying dental substrate.[17,18] Hence, this attribute could obviate the need to replace esthetic restorations after tooth bleaching. In such a scenario, the composite material would adjust its colour to harmonize with

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the newly whitened tooth structure. However, this has not been extensively studied or evaluated to date.

Our study aimed to assess how tooth bleaching affects the colour of restorations made with single-shade composites, the surrounding enamel and the colour difference between them. We hypothesized that using 35% hydrogen peroxide on a restored tooth would lead to comparable colour changes in both the single-shade composite and enamel and no impact on the colour match of the restoration.

## Material and Methods

This laboratory study evaluated the effects of 2 independent variables: composite type — single-shade composites, Palfique Omnichroma (Tokuyama Corp., Tokyo, Japan) and Charisma Diamond One (Kulzer, Hanau, Germany) — and colour match between restorations and the surrounding enamel, before and after tooth bleaching, assessed instrumentally ($\Delta E_{00}$) and visually. In addition, we examined the impact of tooth bleaching on colour changes ($\Delta WI_D$) for both the restoration and the surrounding enamel.

This study used 10 sound, erupted third molars that had recently been extracted. After root removal, a section was made along the distal-mesial direction to separate the buccal and palatine surfaces. Specimens were positioned over a gray portion of the ColorChecker grayscale (X-Rite, Grand Rapids, Mich., USA) and illuminated using a light-correcting device (Smile Lite MDP, Smile Line, St-Imier, Switzerland) equipped with a cross-polarizing filter. Images were captured using an iPhone 8 Plus (Apple, Cupertino, Cal., USA) and white balance was adjusted based on the neutral gray background using Adobe Photoshop Lightroom Classic software (Adobe Systems, San José, Cal., USA).

RGB values were captured for the centre of each specimen (~6 mm in diameter) using the open-source image processing tool ImageJ by the National Institutes of Health (NIH), with each parameter representing a colour channel (R for red, G for green and B for blue). These values were then converted into CIELAB coordinates using the CIE 1931 XYZ colour space and the CIE D65 standard illuminant with a 1931 2° supplementary standard observer.[19–20] Data from the colour coordinates of lightness ($L^*$), the red–green axis ($a^*$) and the yellow–blue axis ($b^*$) were inserted into equation 1 to obtain the value of $WI_D$.[21]

**Equation 1:** $WI_D = 0.551 \times L^* - 2.324 \times a^* - 1.1 \times b^*$

All 20 specimens were ranked based on their $WI_D$ values and grouped into 10 blocks, each containing 2 specimens of similar $WI_D$ values. Within each block, random allocation was achieved by using a list generated on the website, sealed envelope™ (**www.sealedenvelope.com**).

Round preparations were created using a high-speed handpiece and a coarse round diamond bur (#FG 1016, KG Sorensen, Barueri, São Paulo, Brazil) and copious air-water spray. The bur was introduced until its entire active part reached the tooth structure, resulting in preparations approximately 1.8 mm in diameter and depth. The dimensions were verified using a digital caliper, and the preparation margins were maintained without beveling.

For restorative procedures, the enamel surrounding the preparations was selectively etched for 30 s using 37% phosphoric acid (Maquira, Maringá, Paraná, Brazil). Subsequently, the acid was rinsed off with an air-water spray, and the dental substrates were dried using an air stream. The universal adhesive Ambar (FGM, Joinville, Santa Catarina, Brazil) was actively applied, followed by solvent evaporation with a light air stream and light activation for 25 s using a light-curing unit with a potential of 1200 mW/cm$^2$ (Radii-Cal, SDI, Victoria, Australia). The cavities were filled with a single insertion of the composite, with any excess carefully removed before light-curing the restoration for 45 seconds. Finally, the restorations were polished using diamond discs (Sof-Lex, 3M Oral Care, St. Paul, Minn., USA), progressing from coarse to fine granulation.

Before colour assessments, the specimens were immersed in water and stored for a week. We followed the procedure described above to capture images of the restored specimens. Specimens were then bleached with 3 applications of a 35% hydrogen peroxide agent (Whiteness HP Maxx, FGM, Joinville, Santa Catarina, Brazil), lasting 15 min. each, to bleach the specimens. Between bleach applications, the specimens were rehydrated in distilled water for 30 min. Following a 24-h rehydration period in water, the bleached teeth were imaged.

For images taken before and after the bleaching procedures, we digitally assessed the restoration colour using ImageJ software. For this measurement, we confined the reading area to a 1.5-mm region at the centre of the restoration. In parallel, we measured the colour of the adjacent enamel in 4 distinct 1-mm diameter areas on the occlusal, cervical, mesial and distal sides of the restoration (**Figure 1**). To determine the colour of the surrounding enamel, we calculated the average value of these 4 measurements. RGB data were converted to CIELAB colour space using the previously described procedure. $WI_D$ was calculated (**equation 1**) for restoration and surrounding enamel, and the changes in these values caused by the bleaching procedures were calculated for each substrate.

In addition to the initial conversion of colour coordinates into CIELAB coordinates, the data were also converted into the CIELCH system using an MS Excel spreadsheet based on EasyRGB software (Logicol S.l.r., Trieste, Italy). This conversion was necessary to assess the colour difference using the CIEDE2000 formula. In the CIELCH system, $L^*$, $C^*$, and $H^*$ represent lightness, chroma and hue, respectively. The data were then inserted into equation 2 to obtain the colour differences ($\Delta E_{00}$) between the restoration and the surrounding enamel.[22,23]

**Equation 2:**
$$\Delta E_{00}=\sqrt{\left(\frac{\Delta L'}{K_L S_L}\right)^2+\left(\frac{\Delta C'}{K_C S_C}\right)^2+\left(\frac{\Delta H'}{K_H S_H}\right)^2+R_T\frac{\Delta C'}{K_C S_C}\frac{\Delta H'}{K_H S_H}}$$

Where $\Delta L'$, $\Delta C'$, and $\Delta H'$ represent the differences in lightness, chroma and hue, respectively, between the restoration and surrounding enamel. $S_L$, $S_C$ and $S_H$ are the weighted functions for each component. $K_L$, $K_C$ and $K_H$ are the weighted factors for lightness, chroma and hue, respectively ($K_L = K_C = K_H = 1$). $R_T$ is the interactive term between chroma and hue differences.

For visual analysis, the images of both bleached and unbleached specimens were videotaped individually and unidentified against a neutral gray background (Figure 2). Each image was displayed for 5s. The video was shown to 4 dentists who specialize in restorative dentistry or prosthetics on the same 15-inch monitor in a dark room. The order of image presentation was randomized for each evaluation. To assess the colour match between the substrate and the composite resin, the evaluators assigned a score to each image: 1 = perfect, 2 = very good, 3 = good, 4 = poor and 5 = unacceptable. The average scores among the evaluators were used in data analysis.

$WI_D$ data were analyzed using repeated measures (RM) ANOVA, with the factors "composite" and "substrate" (the latter defined as an RM factor). For the analysis of colour match between the restoration and surrounding enamel ($\Delta E_{00}$ and visual analysis), data were also submitted to RM ANOVA, with the factors "composite" and "bleaching" (the latter defined as an RM factor). All statistical analyses were performed with a 95% confidence level using Jamovi 1.6.15 (www.jamovi.org), an open-source statistical software package.

### Ethics Approval

The study protocol (number 5.531.738) was approved by the scientific review committee and committee for protecting human study participants at the Federal University of Sergipe (Brazil) .

## Results

### Colour Analysis Using Image Processing Software

Restorations made with Charisma Diamond One and Palfique Omnichroma exhibited a whitening effect comparable to the bleaching achieved in the surrounding enamel (**Table 1**). RM ANOVA revealed that neither the composite ($p = 0.887$) nor the substrate ($p = 0.447$) had any significant impact on changes in whiteness index values ($WI_D$). In addition, the interaction between these factors was not statistically significant ($p = 0.526$).

Tooth bleaching did not affect the colour discrepancies observed between the restorations and the surrounding enamel (**Table 2**). Both composites exhibited similar colour discrepancies relative to the tooth. Through RM ANOVA, we observed that neither the composite ($p = 0.652$) nor bleaching ($p = 0.314$) had a substantial effect on $\Delta E_{00}$ values. The interaction between these variables was also deemed not statistically significant ($p = 0.592$).

### Visual Analysis

The evaluators' assessments of the colour match between the restoration and surrounding enamel are shown in **Figure 3**. They perceived less matching after tooth bleaching procedures, regardless of the composite evaluated, with no significant difference between resins. RM ANOVA demonstrated that the composite ($p = 0.808$) had no noticeable effect on the visually analyzed colour match (**Table 3**). In contrast, bleaching ($p = 0.031$) did influence the average scores provided by the evaluators. The interaction between these factors was not statistically significant ($p = 1.000$). Colour matches scored lower after the bleaching procedures.

## Discussion

Our results demonstrate that applying 35% hydrogen peroxide to teeth that have been restored with single-shade composites leads to similar changes in the colour of both the resin composite and the adjacent enamel. As a result, the first hypothesis of the study cannot not be rejected. In terms of the colour match between the single-shade composite and the surrounding enamel, the bleaching procedures did not have a significant impact on the colour differences measured using image processing software. However, visual assessment contradicted these findings, as the evaluators rated the colour match better in unbleached restorations. Consequently, the second hypothesis of the study cannot be accepted.

In dental colour evaluation studies, the predominant approach involves employing clinical or bench spectrophotometers to quantify colour changes induced by tooth bleaching or to assess the colour match between restorations and the surrounding substrate.[13–17] Evaluating this latter aspect usually necessitates indirect methods using separate specimens because of limitations in the spectrophotometer's reading area that prevent precise measurement of distinct areas in a single specimen. However, although using images might offer a way to identify colour disparities within a specimen, this method requires ensuring the accuracy of the image's colours compared with the actual specimen.[18,24]

A crucial factor here is standardization, particularly in terms of illumination matching natural daylight. In our study, we employed a light-correcting device set at 5500K, which corresponds to daylight illumination, ensuring consistent and accurate lighting during image capture.[19] Furthermore, we addressed white balance concerns by using a neutral gray background during image acquisition.[18,25] To improve the standardization of image acquisition, we split the specimens along the distal-mesial direction, providing a flat surface opposite the reading area that allowed for consistent positioning and distance from the camera. We also opted for a cellphone camera, instead of a traditional digital single-lens reflex camera. This decision stemmed from the widespread usage of smartphones today, coupled with the advanced features often present in their cameras that facilitate capturing high-quality images.

In studies that examine the colour match of restorations with the surrounding substrate of human teeth, a crucial consideration is standardizing the colour of the substrate. Previous findings have indicated that single-shade composites tend to blend more seamlessly with whiter substrates.[14,15,17] To avoid introducing any bias that could favour composite designed for whiter teeth, it was imperative to maintain a balanced distribution of tooth colours among the different composites. In our study, we tackled this concern by using the natural colour of unprepared teeth, and a block randomization strategy based on the similarity of $WI_D$ was employed. By taking this approach, we are confident that our study minimized any potential biases linked to substrate colour variation, thereby enhancing the credibility and dependability of our findings.

As anticipated, the tooth bleaching procedure using a highly concentrated hydrogen peroxide yielded increased $WI_D$ values in the enamel encircling the restoration, signifying a successful bleaching effect. This outcome arises from the opaqueness of the enamel and the oxidation of organic content in the dentin.[1,2] Of interest, restorations made with the evaluated single-shade composites also exhibited a bleaching effect comparable to that observed in the dental tissue. The capacity of single-shade composites to mimic the natural colour of the adjacent substrates hinges on their heightened translucency.[15,18] This attribute allows these materials to mirror both the surroundings and the underlying substrate, which affects the restoration's final colour. Consequently, the observed whitening in the restorations is partly attributed to alterations in the colour of the surrounding and underlying substrates. Furthermore, prior studies have demonstrated that hydrogen peroxide can lighten resin composites, although this colour shift is less pronounced than observed in tooth tissues.[9–11]

In the assessment involving digitally measured colours, the impact of the bleaching procedures on the colour match between the restorations and the surrounding enamel was not significant. This outcome supports earlier findings that highlighted a comparable bleaching effect on the composites and dental tissues.[26] However, when it came to visual analysis, the bleaching procedure seemed to accentuate certain instances of mismatch. Although assessments based on colour coordinates offer greater objectivity and reduced susceptibility to biases, visual analysis is more clinically relevant; achieving an effective colour restoration match relies on perception by the human eye. Nevertheless, this does not necessarily imply that restorations must be replaced following a tooth bleaching procedure. Notably, the average matching scores for bleached restorations, like the unbleached ones, remained within the range 2 and 3, indicating "very good" and "good" colour matches.

The findings from this study suggest that single-shade composites may be appealing materials for esthetic restorations, particularly for patients who intend to maintain white teeth through frequent bleaching sessions. However, our study focused exclusively on small cavities in molars. Results could vary significantly in anterior teeth, especially visual assessments, as the threshold for esthetic acceptability might be more stringent for these teeth.[27] In addition, 2-mm-deep cavities were used in this study; esthetic restorations typically involve shallower cavities where single-shade composites are expected to perform better.[14] In contrast, deeper cavities are more common in non-esthetic areas and usually require incremental composite insertion. For deeper cavities, a chromatic composite matching the underlying sound dentin should be placed beneath the single-shade composite. Therefore, the bleaching mechanism is unlikely to affect the underlying composite, and the bleaching procedure is likely to enhance the mismatch between the restoration and the surrounding tooth substrate. A similar limitation can also be expected for thin surrounding substrates with a limited dentin.[18]

In this study, visual analyses were conducted by dentists who routinely deal with dental restorations and the esthetic concerns of their patients. Evaluations by laypersons or inexperienced clinicians may be different. Another limitation of the study is that the specimens were only allowed 30 min. for rehydration between bleaching applications; clinical studies indicate that dehydrated teeth require a longer period to regain their colour after isolation removal. No colour measurements were taken between peroxide applications; submerging the specimens in water likely accelerated their rehydration.[28] Finally, other clinical factors, such as tooth aging and exposure to dietary stains, can affect the results, underscoring the need for additional studies focused on colour stability. Further research is imperative to determine whether single-shade composites can maintain a satisfactory colour match after bleaching procedures.

**Table 1:** Mean changes in the whiteness index ($WI_D$) for dentistry caused by tooth bleaching procedures ($n$ = 10).

| Single-shade composites | Mean $WI_D$ (standard deviation) | |
|---|---|---|
| | Restoration | Surrounding enamel |
| Charisma Diamond One | 8.69 (2.27) [Aa] | 6.41 (2.14) [Aa] |
| Palfique Omnichroma | 7.34 (1.63) [Aa] | 7.13 (1.30) [Aa] |

Note: Similar letters (uppercase for comparisons between composites and lowercase for comparisons between measurement locales) indicate no significant difference ($p > 0.05$).

**Table 2:** Mean colour differences ($\Delta E_{00}$) between the restorations and their surrounding enamel ($n$ = 10).

| Single-shade composites | Mean $\Delta E_{00}$ (standard deviation) | |
|---|---|---|
| | Unbleached | Bleached |
| Charisma Diamond One | 2.72 (0.63) [Aa] | 3.66 (0.85) [Aa] |
| Palfique Omnichroma | 3.36 (0.65) [Aa] | 3.65 (0.33) [Aa] |

Note: Similar letters (uppercase for comparisons between composites and lowercase for comparisons between bleaching status) indicate no significant difference ($p > 0.05$).

**Table 3:** Mean scores assigned by evaluators to quality of colour match between the restorations and the surrounding enamel ($n$ = 10).*

| Single-shade composites | Mean evaluator scores (standard deviation) | |
|---|---|---|
| | Unbleached | Bleached |
| Charisma Diamond One | 2.12 (0.30) [Ab] | 2.57 (0.34) [Aa] |
| Palfique Omnichroma | 2.05 (0.15) [Ab] | 2.64 (0.18) [Aa] |

Note: Similar letters (uppercase for comparisons between composites and lowercase for comparisons between bleaching status) indicate no statistically significant difference ($p > 0.05$).

* 1 = perfect, 2 = very good, 3 = good, 4 = poor and 5 = unacceptable.

**Figure 1:** Defined areas for digital colour measurements. The single red circle delineates the centre of the restoration, while the 4 black circles encompass the surrounding enamel.

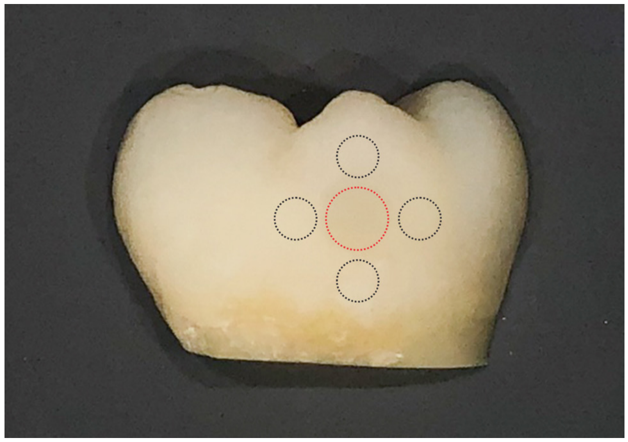


**Figure 2:** Sample images of unbleached (A) and bleached (B) specimens presented for evaluator scoring of colour match between restoration and surrounding enamel.

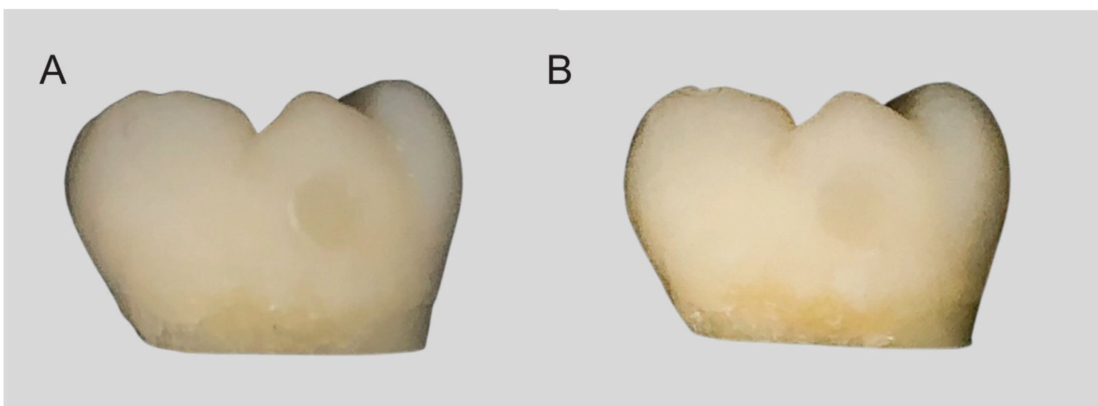
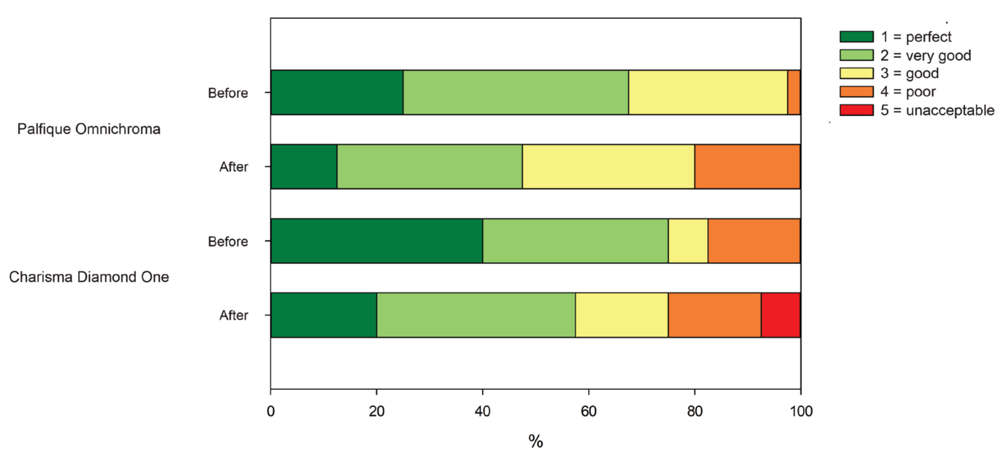



**Figure 3:** Distribution (%) of scores assigned by 4 evaluators of the colour match between 2 single-shade composite restorations and the surrounding enamel before and after bleaching (*n* = 40).



## Conclusion

The use of an image-processing tool for colour evaluation revealed that restorations made using Charisma Diamond One or Palfique Omnichroma exhibited a bleaching effect similar to that observed in the surrounding enamel after tooth bleaching. This successful alignment in bleaching outcomes contributed to the consistent maintenance of colour match. However, visual analysis of images of the same specimens revealed that colour matching was comparatively diminished after the bleaching procedures.

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