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Color stability and degree of conversion of gingiva-colored resin-based composites

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Abstract

Objectives: To evaluate gingiva-colored resin-based composites' (GCRBC) color stability and degree of conversion (DC%).

Methods: Eight discs (8 × 1 mm) of 20 shades of GCRBC were prepared. Color coordinates were measured against a gray background with a calibrated spectroradiometer, CIE D65 illuminant and the CIE 45°/0° geometry at baseline and after 30 days of storage in distilled water, coffee, and red wine. Color differences (ΔE_{00}) between final and baseline conditions were calculated. An ATR-FTIR spectrometer with a diamond tip was used to calculate DC%. The results were analyzed statistically using ANOVA and Tukey post-hoc test. The level of significance was $p < 0.05$.

Results: DC% and color stability correlated with each other and with the GCRBC brand. DC% ranged between 43% and 96%, highest values correspond to flowable composites. All composites have experienced color changes after immersion in water, wine and coffee. However, the magnitude of the color change has varied widely depending on the immersion medium and the GCRBC. Color changes generated by the wine were, globally, greater than those induced by coffee ($p < 0.001$) and above the acceptability thresholds.

Conclusions: The DC% of GCRBCs is sufficient to achieve adequate biocompatibility and physicomechanical properties, but the high susceptibility to staining could compromise aesthetic long-term results.

Clinical Significance: The degree of conversion and the color stability of gingiva-colored resin-based composites correlated with each other. All composites have experienced color changes after immersion in water, wine and coffee. Color changes generated by wine were, globally, greater than those induced by coffee and above the acceptability thresholds that could compromise aesthetic long-term results.

KEYWORDS
CIEDE2000, color stability, degree of conversion, gingiva color thresholds, gingiva-colored resin-based composite

1 | INTRODUCTION

The smile aesthetic is determined by both the teeth and the gingival component. Reproducing the architecture (height, contour, and symmetry) and appearance (color and texture) of the natural mucogingival tissue is essential for the aesthetic success in the anterior sector.[1,2] Several factors can result in the apical migration of the gingival margin, which can expose the root surface and contribute to the accumulation of food debris, altering the dental and periodontal tissues.[3] The treatment of gingival tissue loss may involve surgical, orthodontic, or prosthetic treatments, and in some cases, even a multidisciplinary approach may be necessary.[4]

Gingiva-colored resin-based composites (GCRBC) have been suggested as a cost-effective and minimally invasive solution to camouflage the consequences of gingival recession.[4,5] Commercially available GCRBCs are limited and the research on their performance is scarce compared to that of tooth-colored resin-based composites. Moreover, most studies on GCRBCs are focused on laboratory composites used for indirect techniques.[5,6]

The degree of conversion (DC%) is a crucial characteristic of composite resins since it conditions the color stability, mechanical and physical properties, polymerization shrinkage, and biocompatibility. DC is the ratio of the amount of unreacted carbon double bonds (C=C) present in the polymerized material to the amount present in the unpolymerized material[7] and is conditioned by factors such as matrix composition, filler particles, diluent and initiator concentration,[8,9] and the amount of light received.

The color stability of GCRBCs is critical to maintain a natural and aesthetic appearance over time, as any color changes or discoloration may compromise the treatment outcome and patient satisfaction. Evaluating the color stability of these composites can help to ensure that they are reliable and effective in clinical use, providing patients with a long-term and pleasing result.[10,11] The research on the stability of gingiva-colored resin-based composites after exposure to staining media is minimal, and only two investigations[12,13] studied it. In addition, these studies evaluate color stability without using the recommended CIEDE2000 color difference formula[14,15] or color human gingiva thresholds.[16–18]

This information is crucial for effectively managing GCRBCs and meeting the rising aesthetic expectations of patients. Therefore, the objective of this study was to evaluate the color stability and degree of conversion of gingiva-colored resin-based composites. The null hypotheses tested are: (i) there are no statistically significant variations in the degree of conversion among the GCRBCs evaluated, and (ii) color variations of GCRBCs after exposure to staining media do not exceed their respective perceptibility thresholds.

2 | MATERIALS AND METHODS

2.1 | Sample preparation

Table 1 shows the information of the materials used in this investigation. For samples fabrication, a Tygon tube mold (1 mm height × 8 mm diameter) was employed to prepare eight discs of each shade of every GCRBC system. The mold was positioned on a glass slide, then covered with a transparent polyester Mylar strip to prevent oxygen inhibition and achieve a smooth, clinically relevant surface texture. Next, the resin-based composite was inserted into the mold and compressed using another transparent Mylar strip and a glass slide. Subsequently, light activation was performed according to the manufacturer's instructions using a Bluephase Style light-curing device (Ivoclar-Vivadent, Schaan, Liechtenstein; 1100 mW/cm^2), with the 10-mm light-curing tip placed on the glass slide.[19]

Surface defects of all specimens were evaluated under magnification (10×). The thickness of each disk (1.00 ± 0.05 mm thick) was confirmed by measuring at three different points with a digital caliper (Mitutoyo, Europe GmbH, Germany). Prior to measurements, all specimens were stored for 24 h in 37°C distilled water in a dark chamber. Twelve specimens of each GCRBC were manufactured, and they were randomly distributed for the different analysis: degree of conversion and thermogravimetry ($n = 3$) and color stability ($n = 9$) (Figure 1).

The degree of conversion was calculated from the data obtained in the attenuated total reflection–Fourier transform infrared, and subsequently, the samples were analyzed with thermal analyses.

To evaluate color stability, assigned specimens were measured for color at baseline. Subsequently, disks were randomly distributed into three groups. The samples of the control group ($n = 3$) were immersed in distilled water, group 2 ($n = 3$) in red wine (Don Simon, J. García Carrión, Murcia, Spain) and group 3 ($n = 3$) in coffee (Figure 1). The coffee solution was prepared by dissolving 5 g of soluble instant coffee (Café Diario Eximius Coffee Group, Houston, Texas, USA) in 250 mL of boiling water[20] and purified with a flannel filter.

All specimens were immersed for 30 days,[20] renewing the solutions every 48 h. After that, the composite resin discs were abundantly rinsed, dried with absorbent paper, and the color was measured again.

2.2 | Color measurement and color differences

To measure spectral reflectance, a non-contact measuring system mounted on custom-made optical table was employed. The set-up consisted on a xenon arc lamp (300 W, Newport Stratford Inc., Franklin, MA, USA), two fiber-optic light cables (Model 70050; Newport Stratford Inc., Franklin, MA, USA) illuminating the samples at 45° and a spectroradiometer (PR 670—Photo Research, Chatsworth, CA, USA) a spectroradiometer placed 40 cm in front of the samples, which corresponds with the CIE 45°/0° illuminating/measuring geometry. The measuring aperture of 1° at the center of each specimen was used. Values of spectral reflectance for wavelengths at 2 nm were obtained in the visible range (380–780 nm). All specimens were measured against a 50 × 50 mm gray ($L* = 76.3$, $a* = 9.2$, and $b* = 0.1$) ceramic tile background (Ceram, Staffordshire, UK). Saturated sucrose solution of approximately 1.5 index of refraction was placed as the optical

TABLE 1 Information on the gingiva-colored resin-based composites evaluated in the study. All resin-based composites data were provided by manufacturers.

Material	Manufacturer	Shade (Code)	Batch n°	Composition	Type	Filler content wt%/vol%
Amaris Gingiva	VOCO GmbH (Cuxhaven, Germany)	Natural Pink (AMN)	1,932,473	Monomers: BisGMA, UDMA, TEGDMA. Fillers: silane coated glass ceramic, pre-polymerized filler, silica nanoparticles.	Sculptable Nanohybrid	80%/NC
Renamel Gingafill	Cosmedent (Chicago, USA)	Light Pink (RGL) Medium Pink (RGM) Dark Pink (RGD)	1,646,208 1,646,218 161908A	Monomers: UDMA, BBDMA. Fillers: silicon dioxide and prepolymerized composite (70%), initiators, stabilizers and pigments (<1%). Particle size: 0.04–0.2 μm.	Sculptable Microfilled	70%/60%
PermFlo Pink	Ultradent (South Jordan, Utah, USA)	Pink (PFP)	BH2V6	Monomers: TEGDMA, BisGMA, UDMA. • Fillers: Sodium Monofluorophosphate. • Particle size: 1 μm.	Flowable	68%/NC
AnaxGUM	Anaxdent GmbH (Stuttgard, Germany)	Light Pink (AXL) Dark Pink (AXD) Orange Pink (AXO) Purple Pink (AXP) Brown Pink (AXB)	2,019,006,786 2,020,001,998 2,020,001,526 2,019,006,922 2,011,008,860	Monomers: UDMA, BDDMA, BisGMA. Fillers: anorganic fillers, pyrogenic silica, initiators, stabilizers, pigments. Particle size: 0.04–0.7 μm.	Sculptable Microfilled	74%/NC
Venus Pearl Gum	Kulzer GmbH (Hanau, Germany)	Gum (VPG)	K010030	Monomers: UDMA, EGDMA, TCD-DI-HEA Fillers: Barium Aluminum-boro-fluor Silicate Glass, Silica, Polymer, Titanium dioxide, fluorescent pigments, metallic oxide pigments, organic pigments, aminobenzoicacidester, BHT, Camphorquinone.	Flowable Nanohybrid	NC/59%
Beautifil II Gingiva	Shofu Dental (Kyoto, Japan)	Light (BGL) Dark (BGD) Orange (BGO) Violet (BGV) Brown (BGB) Gum (BGG)	032013 032012 121,904 121,904 121,905 091916	Monomers: BisGMA, TEGDMA Fillers: S-PRG Aluminum-fluor-borosilicate glass. Pigments, others	Sculptable Nanohybrid Flowable Nanohybrid	60–70%

Abbreviations: BBDMA, 1,4-Butanediol dimethacrylate; BHT, butylated hydroxytoluene; BisGMA, bisphenol-A-glycidyldimethacrylate; EGDMA, Ethylene glycol dimethacrylate; HEDMA, hexanediol dimethacrylate; NC, Information not collected; S-PRG, surface pre-reacted glass ionomer; TCD-DI-HEA, 2-propenoic acid, (octahydro-4,7 methano-1H-indene-5-diyl) bis(methyleneiminocarbonyloxy-2,1-ethanediyl) ester; TEGDMA, Triethylene glycol dimethacrylate; UDMA, urethane dimethacrylate.

contact between each specimen and the background.[21,22] Three repeated reflectance measurements without replacement were performed, and the results were averaged.

Spectral reflectance values were converted into CIE $L^*a^*b^*$ color coordinates using the CIE 2° Standard Observer, and the color differences before (basal conditions) and after immersion in the different solutions were calculated for each sample using CIEDE2000 (ΔE_{00}) total color difference formula[14]:

$$\Delta E_{00}(k_L : k_c : k_H) = \left[\left(\frac{\Delta L'}{k_L S_L} \right)^2 + \left(\frac{\Delta C'}{k_C S_C} \right)^2 + \left(\frac{\Delta H'}{k_H S_H} \right)^2 \right.$$
$$\left. + R_T \left(\frac{\Delta C'}{k_C S_C} \right) \left(\frac{\Delta H'}{k_H S_H} \right) \right]^{\frac{1}{2}}$$

where $\Delta L'$, $\Delta C'$, and $\Delta H'$ are the differences in lightness (L'), chroma (C'), and hue (H') between the final conditions (after immersion) and
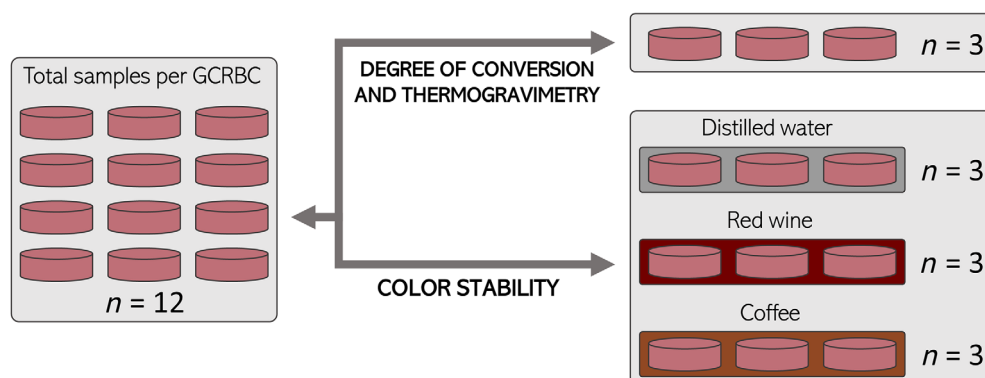
the basal ones, R_T is the rotation function that takes into account the interaction between chroma and hue differences in the blue region. The weighting functions, S_L, S_C, S_H, and the parametric factors, K_L, K_C, K_H, are correction terms for the experimental conditions. Parametric factors were set 1.

The 50:50% perceptibility (PT) and acceptability (AT) color thresholds for human gingiva described on literature[17] ($PT_{00} = 2.1$ and acceptability $AT_{00} = 2.9$) were used to interpret the results.

The ΔE_{00} color variation of each shade of every GCRBC system was analyzed according to values of the CIEDE2000 lightness, chroma, and hue differences.[23] The color differences in CIEDE2000 lightness (ΔL_{00}), chroma (ΔC_{00}), and hue (ΔH_{00}) were defined as[24]:

$$\Delta L_{00} = \frac{\Delta L'}{k_L S_L}; \Delta C_{00} = \frac{\Delta C'}{k_C S_C}; \Delta H_{00} = \frac{\Delta H'}{k_H S_H}$$

The results were interpreted in relation to the respective CIEDE2000 perceptibility and acceptability thresholds for lightness (50:50% PT $\Delta L' = 0.74$; 50:50% AT $\Delta L' = 2.57$), chroma (50:50% PT $\Delta C' = 1.10$; 50:50% AT $\Delta C' = 2.70$) and hue (50:50% PT $\Delta H' = 2.40$).[18] AT $\Delta H'$ may be considered no computable.

2.3 | Attenuated total reflection—Fourier transform infrared—degree of conversion

Samples were analyzed with an Fourier transform infrared (FTIR) JASCO 6200 spectrometer which was fitted with a diamond-tipped attenuated total reflection (ATR) accessory (ATR Pro ONE, Jasco). The samples were positioned on the ATR crystal holder so as to cover the entire crystal surface. All spectra were obtained within the 600 and 4000 cm^{-1} range, with a spectral resolution of 2 cm^{-1}, and acquisition time of 10 s with 10 accumulations. Three samples of each uncured composite material were also analyzed.

To determine the degree of conversion (DC%), spectral analyses were carried out by comparing the area of particular peaks in the spectra obtained from the cured and uncured resin.

Following the implementation of a standard baseline method, a spectral range of 1575–1660 cm^{-1} was selected, and two peaks were considered for DC computation: 1607 cm^{-1} (representing an internal standard aromatic carbon double bond, C=C) and 1637 cm^{-1} (associated with methacrylate, C=C). The DC was calculated as follows:

$$DC\% = \left[1 - \frac{(1637\,\text{cm}^{-1}/1607\,\text{cm}^{-1})_{\text{after curing}}}{(1637\,\text{cm}^{-1}/1607\,\text{cm}^{-1})_{\text{before curing}}}\right] \times 100$$

A curve-fitting software (Peakfit v4.12, Systat Software, Chicago, IL, USA) was employed to resolve the overlapping peaks, and to determine their amplitudes and integrated areas. The second derivative method was employed to resolve the peak calculations within the spectral range, allowing for a variation in peak amplitude and position of up to 5% and ±2 cm^{-1}, respectively.[25,26] The smoothing degree was established at 10% using the Savitzky–Golay algorithm, while a mixed Gaussian-Lorentzian function was used to fit the contours of the bands (i.e., curve shape and width), thereby enabling a detailed and numerical evaluation of DC values. Curve fitting was deemed satisfactory when r^2 values reached 0.995 or higher.

2.4 | Thermogravimetric analysis and differential scanning calorimetry

The loss of mass as a function of temperature was measured by differential scanning calorimetry (DSC) and thermogravimetric analysis (TGA), which were simultaneously performed for the thermal analyses. The STARe TGA/DSC 3+ (Mettler Toledo, Columbus, OH, USA) was used to quantitatively determine the organic and inorganic components of the GCRBC. For this purpose, 25 mg of each sample were analyzed under a synthetic air atmosphere (75 mL/min) at a heating rate of 10°C/min, within the temperature range of 25–1000°C.

2.5 | Statistical analysis

For each of the analyzed parameters, the means and standard deviations were calculated. The normal distribution of the data for all variables was verified by the Shapiro–Wilk test. To determine statistical significance, a one-way analysis of variance (ANOVA) was employed, followed by Tukey post-hoc test. Pearson's correlation analysis was conducted to explore the potential relationships between the different variables. All statistical

analyses were carried out using SPSS 24.0 software (SPSS Inc., Chicago, USA) and OriginPro (OriginLab Corporation, Massachusetts, USA). A level of significance of set at $p < 0.05$.

3 | RESULTS

The degree of conversion (DC%) values of the studied composites (Table 2) ranged between 43% and 96%. PFP obtained the highest

TABLE 2 Mean ± standard deviation of the degree of conversion (DC%), mass lost (%) and calculated filler (%).

	DC%	Mass Lost (%)/Filler (%)
AMN	86.48 ± 1.50[1,3]	34.14/65.65 ± 0.71 [3,4]
RGL	82.56 ± 3.05[2,3,5]	44.40/55.60 ± 0.41[2]
RGM	81.80 ± 8.46[3,5]	43.11/56.89 ± 0.46[2]
RGD	73.46 ± 12.43[4,5,6]	43.44/56.56 ± 0.57[2]
PFP	96.45 ± 0.61[1]	32.12/67.88 ± 1.48[4,5]
AXL	67.33 ± 1.66[6,7]	35.64/64.36 ± 0.67[3]
AXD	72.41 ± 1.34[5,7]	30.04/69.96 ± 0.69[6]
AXO	64.93 ± 2.65[6,7]	32.31/67.69 ± 0.93[4,5]
AXP	42.02 ± 6.95[8]	31.35/68.65 ± 0.72[5,6]
AXB	50.12 ± 4.31[8]	31.84/68.16 ± 1.50[5,6]
VPG	83.59 ± 3.63[2,3,4]	25.09/74.91 ± 1.52[7]
BGL	87.11 ± 2.93[1,3]	31.79/68.21 ± 1.03[5,6]
BGD	86.82 ± 2.45[1,3]	31.06/68.94 ± 0.75[5,6]
BGO	91.38 ± 3.49[1,3]	31.36/68.64 ± 0.36[5,6]
BGV	90.02 ± 0.55[1,3]	30.59/69.41 ± 0.66[5,6]
BGB	88.38 ± 1.27[1,3]	31.34/68.66 ± 0.61[5,6]
BGG	92.67 ± 1.12[1,2]	48.91/51.09 ± 1.01[1]

Note: Read by columns, different numbers show differences statistically significant between composites (values ordered from highest to lowest).

value, followed by BGG and BGO with 92.67% and 91.38%, respectively. The lowest values were obtained for AXP and AXB, showing significant differences ($p < 0.05$) with the rest of the composites and the other shades of the Anaxdent system. In addition, the highest values correspond to fluid consistency materials (PFP and BGG).

Figure 2A-C shows the total CIEDE2000 color difference, and the ΔL_{00}, ΔC_{00}, and ΔH_{00} shifts. All GCRBC composites have experienced color changes after immersion in water wine and coffee. However, the magnitude of the color change has varied widely depending on the immersion medium and the GCRBC. Regarding the immersion medium, the composites stored in distilled water suffer color variations lower than the corresponding perceptibility thresholds ($PT_{00} = 2.1$), except for AXL, VPG and BGG (Figure 2A). Immersion in wine produced color changes above the acceptability thresholds ($\Delta E_{00} > 2.9$) for all GCRBCs evaluated (Figure 2B). In all cases, immersion in coffee resulted in clinically unacceptable color changes except for RGD in which perceptible but acceptable changes occur (Figure 2C). On the other hand, the color changes generated by the wine were, globally, greater than those induced by coffee ($p < 0.001$).

The color changes shifts generated by the wine and coffee were predominantly determined by ΔH_{00}, mainly for Amaris Gingiva and AnaxGUM, and ΔL_{00}. In general, GCRBCs showed ΔH_{00} and ΔL_{00} larger than respective perceptibility thresholds, but ΔC_{00} lower than its PT ΔC_{00} ($\Delta C' = 1.10$),[18] except for AXL, AXB, AXD, and BGG after immersion wine.

The degree of conversion (DC%) and the color change (ΔE_{00}) correlates with the GCRBC brand ($p < 0.001$). Also, DC% correlates with total color differences computed with ΔE_{00} ($p = 0.027$). DC% of different GCRBC brands decreases as follows: Ultradent> Shofu > Amaris Gingiva > Kulzer> Cosmedent> Anaxdent. However, color differences show an opposite trend: Anaxdent> Cosmedent> Amaris Gingiva > Kulzer> Shofu> Ultradent.

In the TGA, BGG is the composite that showed the statistically significant greatest percentage of mass loss (% organic component), followed by the composites of Cosmedent (RGD, RGM, and RGL),
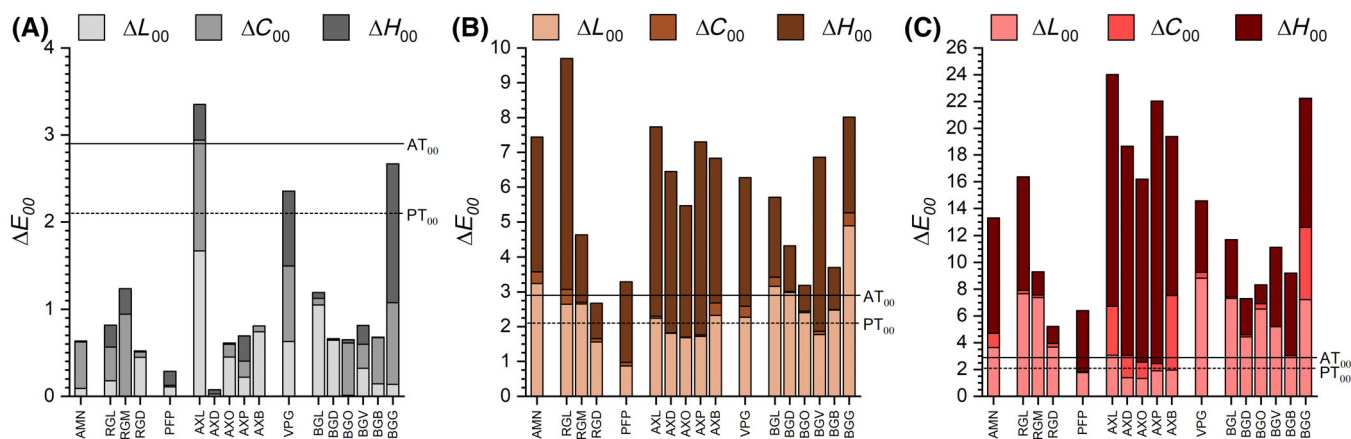

FIGURE 2 CIEDE2000 (ΔE_{00}) color shift for each gingiva-colored resin-based and perceptibility and acceptability threshold interpretation of the influence of the lightness, chroma and hue difference in the total color shifts is shown. (A) Distilled water medium; (B) coffee medium, and (C) red wine medium.

which showed statistically significant differences from the other CGRBC. VPG had a significant lowest percentage of mass lost. Comparing the percentage of filler obtained with those provided by the manufacturers (Table 1) all GCRBCs obtained lower % filler values than those reported. The biggest difference is BGG which shows lower and different values from the rest of the GCRBCs from the same commercial brand and VPG which obtained a high filler percentage, but these data were not reported by the producer.

4 | DISCUSSION

The results of the present research show statistically significant differences in the degree of conversion among the gingiva-colored resin-based composites evaluated. Therefore, the first null hypothesis is rejected.

The results showed a correlation between the DC% and the CIEDE2000 color difference with the GCRBC brand, which is explained by the similar composition of the organic matrix between all the shades of the same composite system. The type and percentage of monomer matrix affects a wide range of critical properties, including color stability, with monomers possessing a more hydrophobic character being more stable.[27] In our study, the composites with the highest degree of conversion values, and the lowest color changes, are composed of triethylene glycol dimethacrylate (TEGDMA), urethane dimethacrylate (UDMA) and hydroxyethyl methacrylate, in the case of Ultradent, and TEGDMA and BisGMA in the Shofu composites. In general, composites whose organic matrix contains high viscosity (high molecular weight) monomers, such as BisGMA, do not achieve a high DC%. Other monomers (TEGDMA, UDMA, and BisEMA) that reduce viscosity are usually added to optimize the degree of polymerization. Different studies show that the DC% increases with the addition of these monomers in the following order[28]: TEGDMA > UDMA > BisEMA > BisGMA. Therefore, it is justified that the materials that include TEGDMA in their composition reach higher degree of conversion. UDMA-based composites[29] should also achieve higher DC% than those based only on BisGMA. However, a previous study[30] showed that the addition of UDMA increases the difference between the refractive index of the matrix and that of the filler, which, as we will see in another study,[31] determines lower translucency and, ultimately, lower degree of conversion percentage. This data could justify that the DC% of Renamel Gingafill (73%–82%) formulated with UDMA does not differ significantly from other composites prepared with BisGMA. Finally, light absorption is linked to the nature and concentration of the pigments added to the composite to achieve a specific color.[32] It could explain why the most saturated materials from each brand (dark and orange shades: AXO, RGD, BGD) obtain less degree of conversion than CGRBC's same composition; but, on the other hand, have more color stability, which could be due to its high chromaticity doing the color change will be less evident.

Although this result could be related to the composition of the matrix or the shape and size of the filler, the thermogravimetry findings suggest that the filler percentage in GCRBC is actually lower than the reported value, therefore the information provided by the

manufacturers is insufficient, limiting the discussion about how different these materials are and the reason for their similar behavior in terms of color stability. For example, BGG obtained a high DC% value (92.67%) and obtained the highest color change after exposure to water, coffee, and wine. This could be explained by the thermogravimetric analysis data, which determined that BGG had a significantly higher percentage of organic matter than the rest of the studied composites.[8,33]

A previous study[13] reported color changes greater than 2.7 in CIELAB units in gingival composites stored for 21 days in tap water. It is possible that mineral salts, fluorides and other electrolytes, absent in distilled water and present in tap water, when absorbed by the organic matrix, significantly increase the instability of the red pigments present in these materials.[34] However, our study report that, in general, color changes in gingival composites stored for 30 days in distilled water are lower than $PT_{00} = 2.1$ CIEDE2000 units, and lower than 1.0 units in most cases (Figure 2A). Thus, the difference in the type of water used for storage (tap water versus distilled water) could justify the values of the color differences found.

On the other hand, the color changes generated by wine were, globally, greater than those induced by coffee ($p < 0.001$), but both produced clinically unacceptable color changes (above the acceptability threshold) in all composites, and, therefore the second hypothesis is rejected. Consistent with these data, previous studies on tooth-colored composites[35,36] reported greater wine potential than coffee or tea to induce coloration.[37] This effect is justified by the presence of tannins and the slightly acidic pH of the wine, which would soften the resin matrix.[38] On the other hand, two previous studies[12,13] reported color stability results of GCRBC, and they found a greater susceptibility of gingival composites to staining with coffee compared to wine. The type of wine used in our study may explain these differences, but future research would be necessary to clarify this point.

Color stability varied between composite brands (Figure 2B,C) which would be explained by differences in the amount and composition of the organic matrix (type and concentration of monomers). Regarding color variation, the total color shift was influenced by the value of lightness, hue and chroma differences.[23] The findings of the present study showed that the color change after storage in both wine and coffee occurs fundamentally at the expense of the hue and the lightness with differences visually unacceptable.

It has been estimated[39] that immersion for 24 h in a chromogenic solution is equivalent to 1 month of real exposure, so the immersion period established in this study would be clinically relevant. On the other hand, the decision to polymerize under a Mylar matrix and not polish the samples was made due to the difficulty in standardizing the results of manual polishing. Considering the significant correlation between color stability and roughness,[40,41] the absence of a finishing and polishing phase in the study can be viewed as a limitation. Including this phase would have better simulated the material's usage under clinical conditions.

In short, studies must continue to be carried out on gingival composites to gain an in-depth understanding of their composition and link it with their mechanical, optical, and biological properties. In this

way, they will be a reliable treatment alternative for cervical defects associated with gingival recession. The interpretation of the color stability results against the recently published color thresholds for the gingival color space, and CIEDE2000 lightness, hue, and chroma human gingiva thresholds, used in this study, can a step one for help the clinician select the most appropriate gingival composite in each clinical situation.

5 | CONCLUSIONS

Within the limitations of this in vitro study, the color stability and degree conversion of gingiva-colored resin based-composites (GCRBC) were affected by immersion medium. DC% and the color stability correlated with each other and with the GCRBC brand. All composites have experienced color changes after immersion in water, wine, and coffee. However, the magnitude of the color change has varied widely depending on the immersion medium and the GCRBC. Color changes after storage generated by the wine were, globally, greater than those induced by coffee and both above the visual acceptability thresholds. This color change is generally at the expense of the hue and lightness changes.

In short, the DC% of GCRBCs is sufficient to achieve adequate biocompatibility and physicomechanical properties, but the high susceptibility to staining could compromise aesthetic long-term results.

CONFLICT OF INTEREST STATEMENT
The authors do not have any financial interest in the companies whose materials are included in this article.

DATA AVAILABILITY STATEMENT
The data that support the findings of this study are available from the corresponding author upon reasonable request.

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