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Research Article

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Comparison of instrumental methods for color change assessment of Giomer resins

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ABSTRACT

Objectives: The aim of this study was to compare the color change of the Giomer resin composite (Beautifil-Bulk) by using photographs obtained with a smartphone (iPhone 6S) associated with Adobe Photoshop software (digital method), with the spectrophotometric method (Vita Easyshade) after immersion in different pigment solutions.
Materials and Methods: Twenty resin composite samples with a diameter of 15.0 mm and thickness of 1.0 mm were confectioned in A2 color ($n = 5$). Photographs and initial color readings were performed with a smartphone and spectrophotometer, respectively. Then, samples were randomly divided and subjected to cycles of immersion in distilled water (control), açai, Coke, and tomato sauce, 3 times a day, 20 minutes for 7 days. Later, new photographs and color readings were taken.
Results: The analysis (2-way analysis of variance, Holm-Sidak, $p < 0.05$) demonstrated no statistical difference ($p < 0.005$) between the methods in all groups. Similar color changes were observed for all pigment solutions when using the spectrophotometric method. For the digital method, all color changes were clinically unacceptable, with distilled water and tomato sauce similar to each other and with statistical differences ($p < 0.005$) for Coke and açai.
Conclusions: Only the tomato sauce produced a color change above the acceptability threshold using both methods of color assessment. The spectrophotometric and digital methods produce different patterns of color change. According to our results, the spectrophotometric method is more recommended in color change assessment.

Keywords: Aesthetics; Coloring agents; Composite resins; Image processing, computer-assisted; Spectrophotometry

INTRODUCTION

Color analysis has been constantly studied in dentistry to assess the color change of several restorative materials, as it is the most important aesthetic parameter to be evaluated [1].

Author Contributions
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Color measurements can be performed by different methods: subjective, such as visual and objective, with the use of different equipment such as colorimeters, spectrophotometers, and more recently, through the analysis of photographic images [2,3].

Since the late 1970s, digital instruments such as spectrophotometers have been developed and improved to obtain objective data from color analysis [4]. Spectrophotometers measure the amount of light reflected by an object in the 1–25 nm range of the visible spectrum, at a wavelength range of 380–720 nm. They are capable of detecting minimal color differences in a spectrum not detected by the human eye [2,5].

Among the digital methods for color analysis, several image editing software packages are available and have a relevant role in the virtual industry, including dentistry. Initially, this method was used to improve communication between the dentist and laboratory technicians while choosing the color [3]. Currently, data from the complete color spectrum can be obtained when the photographs are analyzed by appropriate software, providing quantitative data with lower costs [6] compared to the acquisition of a spectrophotometer.

Instrumental measurements obtained by spectrophotometers or image editing software can quantify color and facilitate measurements, making them more objective and accurate. Such methods present their color measurements in the CIELAB System (International Color Association, L * a * b * system), and promote a comparison of the color parameters of different objects when analyzed mathematically [7].

Improvements and comparisons of color measurement methods are necessary to prove their effectiveness, reduce equipment costs by using simpler methods, and popularize them. Smartphones, software, and digital cameras have been used *in vivo* and in clinical investigations for color studies. These tools, including smartphones, have become more available and used. However, these new methods need to be validated in the literature. A few studies had evaluated color change through photographs obtained with smartphones and compared them with the spectrophotometer [8]. In addition, new restorative materials such as resin composite Giomer have been used in daily clinical practice, meaning that its properties must be studied, including color stability.

The aim of this study was to compare digital methods using photographs taken with a smartphone (iPhone 6S, Apple, San Jose, CA, USA) associated with Adobe Photoshop software (Adobe Photoshop CC 2018 software, Adobe Systems Incorporated, San Jose, CA, USA) and the spectrophotometric method (Vita Easyshade, VITA Zahnfabrik H. Rauter GmbH & Co. KG, Bad Säckingen, Germany) of color change of the resin composite Giomer (Beautifil-Bulk, Shofu Inc., Kyoto, Japan) submitted to immersion cycles in pigment solutions. The tested hypotheses were: 1) There was no difference in the color stability of the resin composite depending on the color evaluation method; and 2) There was no difference in the color stability of the resin composite due to the pigmenting substances used concerning the control group.

MATERIALS AND METHODS

Twenty samples of Giomer resin composite (Beautifil-Bulk, Shofu Inc.) were produced according to the manufacturer's specifications, using a circular metal matrix with dimensions of 15.0 mm in diameter and 1.0 mm in thickness, in color A2. The material was inserted in a single increment in the matrix and was interposed by glass slides to promote the containment of the material and form flat and smooth surfaces. Photoactivation was performed perpendicularly with the Radii Cal Plus light curing device (SDI, Melbourne, Australia) at 1,000 mW/cm^2 and in contact with the glass slides, for 40 seconds. Samples were removed from the matrix and the finishing was achieved with scalpel blades (15c). Afterwards, samples were visually inspected and included in the experiment when the surface was homogeneous and free of cracks and/or air bubbles. They were kept in a dark room for 7 days, in a dry environment, at 37°C following ISO 4049: 2009 [9].

For the digital method, 5 photos for each sample were taken with an iPhone 6S smartphone (Apple) in Raw format. The smartphone was fixed statically to a camera stick (VX Case, Belo Horizonte, Brazil) at a distance of 30 cm away from the specimen, and standardized light through an EVOBOX metamerism box (EVOBOX, São Paulo, Brazil), equipped with 6000K artificial LED. Then, the images were digitally analyzed by the Adobe Photoshop CC 2018 software (Adobe Systems Incorporated). The samples were also subjected to color analysis with the spectrophotometer (Vita Easyshade), previously calibrated on a ceramic base provided by the manufacturer. The device tip was placed perpendicular to the center of each specimen, to obtain data referring to the CIE-Lab scale. Color readings were performed in triplicate against a white background [10] and the mean value obtained from each sample was used. A flowchart (**Figure 1**) summarizes the used methodology.

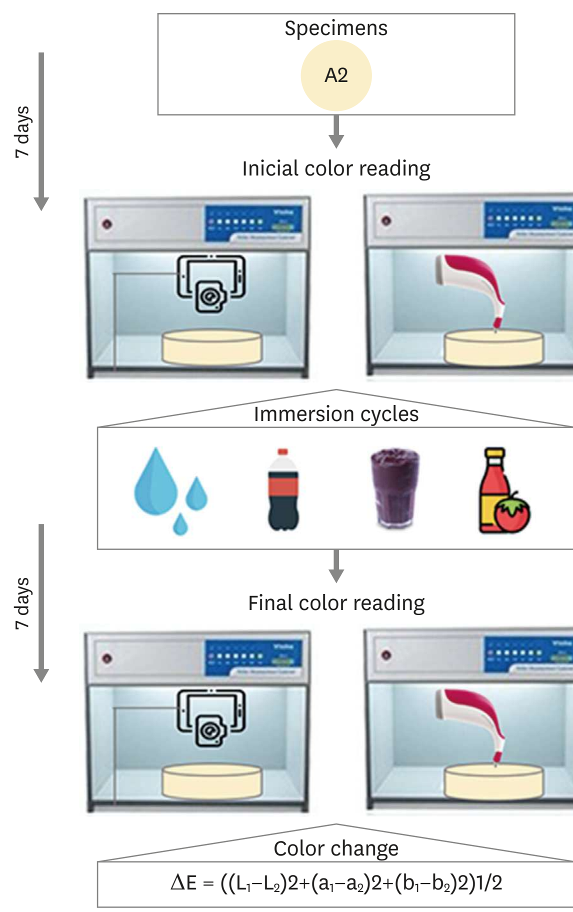

Figure 1. Flowchart summarizing the methodology.

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In sequence, the resin composite samples were randomly divided into 4 groups ($n = 5$) [11]. Their allocation sequence was randomized using Microsoft Excel 2018 software (version 16.16.3 for MacBook, Microsoft, Redmond, WA, USA). The control group was kept in distilled water for 7 days at 37°C and the other 3 groups underwent cyclic immersions in açai juice (Juice Amazoo, Traditional Açaí), tomato sauce (Tomato Sauce Carrefour) and Coke for the same time and at the same temperature. The immersion cycles were 20 minutes, 3 times a day in 25 mL of each solution in its commercial form, with no preparation or dilution of the product. After removing the samples from the pigment solutions in each cycle, they were washed and kept in distilled water. The immersion cycles occurred for 7 consecutive days, with solutions being changed daily [12].

After the seventh day of immersion, samples were washed passively in distilled water for 3 minutes, dried with absorbent papers, and new photographs and color readings by the spectrophotometer were performed. The images were again digitally analyzed by the Adobe Photoshop CC 2018 software using the histogram tool, converting them to the CIELAB System (International Color Association) [13]. Values of the coordinates of color L * a * b * were obtained. Then, they were imported into a Microsoft Excel spreadsheet and the color evaluation was performed by the CIELAB System. This is composed of 3 axes, where L * is an indicator of the light of the color measured from black (L * = 0). For white (L * = 100), a * determines the color in the dimension of red (a * > 0) and green (a * < 0), and b * determines the color in yellow (b * > 0) and in the blue dimension (b * < 0).

The L * a * b * data were obtained by averaging 3 readings of each sample with the spectrophotometer and the editing software. The color variation was calculated using the formula ΔEab = ((ΔL) 2 + (Δa) 2 + (Δb) 2) 1/2 in 2-time intervals: initial and after 7 days. Here, ΔEab * is the color change, ΔL * = L * F − L * I, Δa * = a * F − a * I and Δb * = b * F − b * I. The ΔEab * values were calculated using Microsoft Excel software.

L * I, a * I, and b * I are referred to as the initial color measurement and L * F, a * F, and b * F as the final color measurement.

Values of ΔEab equal to or greater than 2.7 were considered clinically unacceptable based on the acceptability threshold [1]. The data were analyzed using the analysis of variance (2-way analysis of variance [ANOVA]) and Holm-Sidak test with the SigmaStat 4.0 software (Sigma Stat Inc., San Jose, CA, USA), with a 95% significance level. A power test was performed considering $n = 5$, means and standard deviation for ΔE of both methods, spectrophotometer and digital method at software OpenEpi version 3.01.

RESULTS

Table 1 shows the comparison of means (2-way ANOVA and Holm-Sidak, $p < 0.05$) and standard deviation of ΔL, Δa and Δb from the CIE-Lab scale, for each color evaluation method used, digital and spectrophotometer, regarding pigment substances.

When analyzing ΔE values, color analysis methods ($p < 0.001$) and pigment solutions ($p = 0.011$) affected the results. The digital method showed higher ΔE values when compared to the spectrophotometric method ($p < 0.05$). There was a significant statistical difference in the values of ΔE between pigment solutions when the digital method was used ($p < 0.05$): water > açai ($p < 0.001$), water Coke ($p = 0.003$), tomato sauce > açai (p = 0.021).

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Table 1. Results of ΔE, Δa, Δb and ΔL

Variables		Water	Coke	Açaí	Tomato sauce
ΔE	Spectrophotometric	1.30 (0.60)^{Aa}	1.96 (1.55)^{Aa}	2.16 (1.14)^{Aa}	3.35 (1.84)^{Aa}
	Digital method	11.95 (1.25)^{Ab}	6.91 (3.49)^{BCb}	6.17 (2.28)^{Bb}	10.12 (2.93)^{ACb}
ΔL	Spectrophotometric	−0.41 (0.66)^{Aa}	−0.46 (0.77)^{Aa}	−0.39 (1.63)^{Aa}	0.83 (1.41)^{Aa}
	Digital method	5.20 (2.78)^{Ab}	5.56 (2.92)^{Ab}	−0.32 (4.57)^{Ab}	4.16 (3.75)^{Ab}
Δa*	Spectrophotometric	−0.20 (0.47)^{Aa}	−0.88 (0.54)^{Aa}	−0.67 (0.60)^{Aa}	0.52 (0.58)^{Aa}
	Digital method	−2.56 (0.67)^{Ab}	0.24 (0.74)^{Ba}	−0.88 (1.46)^{Ba}	0.44 (1.19)^{Ba}
Δb*	Spectrophotometric	−0.25 (1.21)^{Aa}	0.61 (2.36)^{Aa}	0.64 (1.66)^{Aa}	2.44 (2.54)^{Aa}
	Digital method	10.16 (0.86)^{Ab}	3.28 (3.27)^{Ba}	−0.40 (5.36)^{Ba}	8.52 (2.92)^{Ab}

The values are mean ± standard deviation.
Different letters, lower-case in the column, and capitals letters in the row indicate significant statistical results. (p < 0.05).

When comparing the solutions, similar color changes were observed for all pigment solutions when using the spectrophotometer. However, the color change of the group immersed in the tomato sauce was clinically unacceptable (ΔE > 2.7). For the digital method, all color changes were clinically unacceptable, with distilled water and tomato sauce being similar to each other (p < 0.001) and a significant statistical difference (p < 0.005) for Coke and açai, indicating that they were also similar to each other.

As for the L coordinate, the color assessment methods seemingly showed a statistically significant difference (p < 0.001) in all groups. There was no statistically significant difference in the color change when different pigment solutions were used (p = 0.054).

Analyzing the a * coordinate, when comparing both the spectrophotometer and digital methods, there is a significant statistical difference between the groups (p = 0.038) when samples were stored in water. Pigmenting substances also affected the a * coordinate results. For the digital method, the values of the Coke, tomato sauce, and açai groups were similar, but they were different from those found for samples stored in water (p < 0.001).

Both variables affected the results of the b coordinate (p < 0.001). The multiple comparisons between groups indicated that the values of Δb for the digital method were higher than those presented by the spectrophotometer. The comparison between solutions indicated that storage in tomato sauce gave different results to storage in açai, with a similar difference between water and açai, and tomato sauce and Coke.

DISCUSSION

This present study aimed to compare the color change of Giomer resin composite (Beautifil-Bulk) performed by the digital method, with photographs obtained using a smartphone associated with Adobe Photoshop software, and the spectrophotometric method Vita Easyshade. The null hypotheses tested were that there was no difference in the color stability of the resin composite depending on the color evaluation method and pigment substances used. The results of the study indicate that both null hypotheses were rejected, as there was a difference in color stability between the methods of analysis for all groups and patterns of color change were different according to the type of pigment substance, regardless of the measurement method used.

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Both spectrophotometric and digital methods allow color analysis in the 3-dimensional CIE L * a * b * space. Although it is not the most up-to-date system to evaluate color, CIELAB is the most commonly used system to express the visual perception related to color and its clinical significance therefore being considered objective [14].

Image processing and editing software, such as Adobe Photoshop and Corel Photo-Paint (Corel, Ottawa, Canada), have several assignments within dentistry. However, other methods such as spectrophotometers and colorimeters are preferred in research, having already validated data [15]. Therefore, due to the relatively high cost of portable spectrophotometers, there is a need to study the accuracy of alternative methods. In this study, results show values of ΔE with the same pattern of variation when the color of the samples was analyzed by spectrophotometry, which is more reliable due to the reproducibility of the device. Such results corroborate those of previous studies pointing to the spectrophotometer (Vita Easyshade) as a precise method concerning reproducibility for color analysis both *in vitro* and *in vivo* [16-18].

In contrast, when using a photography camera together with the image editing software, Anand *et al.* [19] obtained results indicating that color analysis performed by digital methods was similar to that performed by spectrophotometry regarding the values of L * and b *. In the present study, the results for both methods were different, and the difference in color values as a result of using a smartphone to take the photographs can be speculated, as devices are influenced by ambient light, even with the presence of internal correction algorithms [20] and the use of a metamerism box to take photographs. Miyajiwala *et al.* [6] obtained accurate results in an *in vivo* study, according to the variation coefficient ($\Delta E < 2.0$) when using a photo camera. It is claimed that a grey card must be used in the same photograph for camera calibration and to eliminate shadows when analyzing the image in the software. For all color change values, ΔE was evaluated with a perceptibility threshold of 1.2 and an acceptability threshold of 2.7 This value is based on the visual interpretation and instrumental findings [1]. The samples showed clinically unacceptable color changes when analyzed by the digital method ($\Delta E > 2.7$). Significantly higher values for the change in the luminosity axis (ΔL) in this method may be related to the light instability promoted by the method itself, as demonstrated by Tam and Lee [20] when analyzing the digital method. Regarding the spectrophotometer, the device has an integrated and standardized light source, avoiding the influence of ambient light in the color analysis [21].

When analyzing the color change of the Giomer resin composite, it was found that pigmenting produced significant color changes, which was corroborated by the study by Gonulol *et al.* [22], where Giomer showed greater color changes even when evaluated by spectrophotometry, and high-water sorption values compared to conventional resin composite. The color change for Giomer can be related to its fluoride release properties, as well as the surface of glass particles which generate an osmotic effect, inducing water absorption, and, consequently, a greater color change [23,24].

When analyzing the pigmentation of Giomer, Choi *et al.* [11] obtained significant color changes after 5 days of immersion of the resin composite in the control group (water), Coke, orange juice, coffee, and energy drinks. In the present study, changes in color in the experimental groups analyzed were verified. Regarding the color change promoted by the liquid Coke, due to its pH, it possibly affects Giomer's microhardness, causing water absorption and hydrolysis between the resin matrix and the charged particles, and consequently influences the surface integrity of the resin composite [11,25]. No study has assessed the pigmentation of Giomer resin composite by açai and tomato sauce. Açai, like grapes, contain anthocyanins, consisting of strong colored pigments, such as red, purple, or blue. These pigments are hydrophilic and can cause pigmentation due to their absorption on the surface of the resin composite [26,27]. It explains the negative values of the L, a, and b axes, tending towards a darkened coloration for green and blue tones. Regarding tomato sauce, positive values of axis B are observed, showing a strong tendency towards redness in the samples, probably explained by the presence of lycopene, a carotenoid substance that is responsible for the reddish color of tomatoes, watermelons, and guava, among other foods [26]. Besides, tomato sauce is mostly composed of water, justifying similar results to the control group in the digital method.

More accessible color assessment methods should be clinically studied and technically improved to reach a greater number of clinicians and become a simple, effective, and routine procedure in daily clinics. For the present study, we performed the *in vitro* study with only one type of resin composite and the pigmentation simulation, through immersion cycles limited to 4 types of pigmenting substances. Also, the metamerism box could be replaced by the use of a lightbox, improving standardization during the color measurement of samples. Other resin composites can be used to evaluate color change and compared with the resin composite Giomer. The comparison of different smartphone camera models, professional digital cameras and the use of other color change calculations, such as CIEDE 2000, should be considered in future research.

CONCLUSIONS

It was concluded within the limitations of this *in vitro* study that there are differences in color change due to the color analysis method used. The color changes of the resin composite Giomer (Beautifil-Bulk) measured by the spectrophotometric method were clinically acceptable, except when immersed in tomato sauce. The color changes of the resin composite Giomer (Beautifil-Bulk) measured by the digital method were of greater magnitude and clinically unacceptable compared to the spectrophotometric method. Of all of the pigmentation solutions, only the tomato sauce was able to produce a color change in both methods of color assessment. Therefore, according to our results, the spectrophotometric method is more recommended for color change assessment.

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