Instrumental Colorimetric Evaluation of Direct Enamel Restoration Materials

Rodrigo Rubio[1], Danilo Giusto[2], Fernanda Hitschfeld[3], Raimundo Sarmiento-Oesterreich[4] and Jaime Sarmiento-Cornejo[5,*]

[1]*Gustavo Fricke Hospital, Viña del Mar, Chile. Operative Dentistry Department, School of Dentistry, University of Valparaíso, Valparaíso, Chile*

[2]*Operative Dentistry Department, School of Dentistry, University of Valparaíso, Valparaíso, Chile*

[3]*University of Valparaíso, Valparaíso, Chile*

[4]*Chilean Navy, Dental Service. Operative Dentistry Department, School of Dentistry, University of Valparaíso, Valparaíso, Chile*

[5]*Chilean Navy, Dental Service. Operative Dentistry Department, School of Dentistry, University of Valparaíso, Valparaíso, Chile*

Abstract: Evidence establishes that there are problems regarding colorimetric coding and standardization of composite resin codes around the world that make the work of clinicians difficult. Determine significant quantitative colorimetric differences (ΔE) in enamel composite resins VITA A2 and A3 respect to VITA-Classical shade, allows clinicians to be alerted to real color differences between products of the same coding.

Descriptive *in vitro* study, 6 resins (N 140) A2 and A3 were used. 7 mm diameter discs, 1 mm (+/-0.1mm) thick were made, measured with spectrophotometry on opaque black background in dark chamber. Values obtained in CIELAB were analyzed obtaining ΔE. ANOVA test of factor 1 (α0.05) was performed.

ΔE for products simulating A2 and A3 with respect to Vita-Classical scale was greater than 5 (5= evident instrumental color difference between reference color and obtained color, unacceptable), with exception of A3 FiltekZ350XT (3MESPE, Saint Paul, Minnesota, USA) (3.39±.65) (3 to 4= evident instrumental color difference between reference color and obtained color, but not visually perceptible).

There are significant colorimetric differences in enamel composite resins with VITA A2 and A3 coding in studied products, with respect to original VITA-Classical color, when measured spectrophotometer in CIELab with an interval confidence of 95%. All resins are over ΔE 5, meaning that differences between shades are considered clinically unacceptable, with exception of FiltekZ350XT 3MESPE, (3.39±.65) for Vita A3. None of the composite resins meet colorimetric characteristics when compared to Vita-Classical scale, (Bad Säckingen, Germany).

Keywords: Esthetics, Dental, Color, Spectrophotometry, Biomimetic materials, Rehabilitation.

INTRODUCTION

The selection of tooth color has a diversity of factors influencing the process. It requires knowing and understanding everything related to tooth and restorative material chromatic behavior [1, 2].

Dental companies have made efforts to simplify shade selection. First precedent is found in the company VITA-Zahnfabrik, (Bad Säckingen, Germany), with its VITA-Classical scale, introduced in 1956. On this basic scale of colors arranged in a practical way according to chromatic tones, some dental companies began production of composite resins designed for direct restorations, using VITAPAN Classical scale as a reference.

Tooth color selection is commonly done visually. This method is based on the use of color samples, being VITA Classical the most used worldwide even today [3].

Despite introduction of new and improved shade scales by VITA, the shades on the market continue, mainly to be produced based on VITA-Classical scale.

Additionally, devices have been developed to measure the color of teeth and restorative materials, in order to facilitate color selection. Spectrophotometers are colorimetric measurement instruments that aim to solve part of the problem exposed for objective selection. Their use has had a heterogeneous response, finding studies that support as well that disqualify them for clinical and implementation reasons.

In parallel, technique of reproducing tooth by color layers emerged, restoring its anatomy step by step,

*Address correspondence to this author at the School of Dentistry. University of Valparaíso-Chile, Subida Carvallo 211, Valparaíso, Chile;
E-mail: jaime.sarmiento@uv.cl

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differentiating dentin from enamel and including effects. Stratified technique represents a new level of difficulty, which is why instrumental color measurement has become more frequent used [3]. VITAPAN-Classical scale, although originally developed for indirect non-resinous materials, is a common starting point for determining composite resin colors. However, many problems are discovered when trying to integrate different brands of composite resin into a universal guide, and it has been shown that there is a need to improve the standardization of composite resins [4].

Composite resin systems based on the classic VITA scale must be measured and evaluated in terms of compliance and reproduction of the VITA shade that they claim to represent, in order to check whether the A2 or A3 composite resin, for example, of a commercial brand, varies from others. The following study was carried out, where a group of 6 enamel composite resins on the market in their most common shades A2-A3 were selected for instrumental measurement using the VITA-Easyshade-V spectrophotometer and thus evaluate its color reproduction against the corresponding VITA-Classical scale [5].

MATERIALS AND METHOD

Descriptive *in vitro* study without biological samples, based on the preparation and observation of composite resin samples from six different brands were used in shades A2 and A3.

Universe of this study is all A2 and A3 enamel composite resins, which establishes that the most common tooth colors in study population is A2 and A3 [6].

The sampling was selected by convenience, and all enamel composite resins commercial brands obsolete and that do not use the VITA-Classical nomenclature, were excluded.

Definition of variables, as dependent variable: color. As conceptual definitions: the light that illuminates an object under natural conditions is white as a mixture of all the colors of the visible spectrum. An object presents color when its surface is capable of absorbing a certain wavelength. An object is recognized as a specific color when it reflects one or more wavelengths. As an operational definition, the mathematical differences between the values of L*, a* and b* of the different products in each tone were established. It is calculated with the averages of the L*a*b* values of the samples using the following equation: ΔE*= {(ΔL*)2 + (Δa*)2 + (Δb*)2}1/2.

Regarding the independent variables, the CIE L*a*b values corresponding to each sample were considered. As a conceptual definition: color classification in a three-dimensional manner, where the *L axis is value or brightness that goes from 0 to 100 where 0 is black and 100 is white. The *a axis represents the reddish-greenish variation, where the positive values of the a axis correspond to reddish coloration and the negative values to greenish coloration and the *b axis to bluish yellowish color, where the positive values correspond to the yellow color and the negative values to the color blue. If these axes are 0, it is because they are achromatic. As an operational definition: L* a* and b* values of the CIE L*a*b system obtained by means of a digital colorimeter for each sample.

Study considered: preparation, coding and color measurement of 140 enamel color composite resin samples of shades A2 and A3. Through a pilot study, the sample size calculation was carried out. This pilot study aims to be able to present the data acquired following the methodology established from the beginning to analyze distribution of data, the number of samples per group and look for a trend in the data to approximate the results of the real study.

Study methodology is established by the working group and therefore its main objective becomes of statistical importance only.

A descriptive analysis of data was carried out, a statistical test of normality of data distribution and finally a 1-factor ANOVA.

For samples, composite resin systems were used with an expiration date that exceeded the end date of the experimental phase by at least 6 months. Syringes of Enamel A2 and A3 from the following systems were selected: FiltekZ350XT 3MESPE, (Saint Paul, Minnesota, USA); EmpressDirect-IvoclarVivadent, (Schaan, Liechtenstein); BrilliantNG-Coltène, (Altstätten, Switzerland); Opallis-FGM, (Joinville, Santa Catarina, Brazil); HerculiteXRVUltra-Kerr, (Brea, California, USA); Glacier-SDI, (Bayswater, Perth, Australia).

Each operator used all safety barriers to avoid sample contamination. The entire procedure was carried out in the Operative Dentistry Laboratory, University of Valparaíso-Chile.

Operator called “A” prepared all the samples. For each resin syringe, discs were made with a thickness of 1 mm (+/-0.1 mm) and a diameter of 7 mm. A single pattern made of two-piece metal was used, a metal base and a screw cap in which a circular opening of 7mm diameter and 1mm depth is located.

Preparation process for samples: the former was opened and cleaned with sterile gauze and 90% alcohol. A polyacetate strip was placed at the base of the former. The screw cap was closed on the former until the polyacetate strip was trapped. Composite resin was portioned from the syringe with a PFI HU-Friedy-XTS, (Chicago, Illinois, USA), spatula and applied to the former, filling it completely in 1 increment. A polyacetate strip was placed on the former and a Petri dish on top of it. Applying pressure with the Petri dish, the discs were initially light-cured for 20-seconds. A second 20-seconds photopolymerization was performed without the slide, maintaining the polyacetate band. The former was opened, leaving the lid separate from the former, and the underside of the disk was photopolymerized for 20-seconds. Samples were stored in labeled plastic bags inside a plastic box that was coded and divided by tone and brand.

Photopolymerization was carried out with an Ivoclar-Bluepahse5, (Schaan, Liechtenstein), LED lamp with a constant intensity, on all three occasions.

Operator called “B” was in charge of labeling and storing the samples. For each composite resin syringe, 10 discs were made and packaged in individual plastic bags. The samples were labeled according to the radial alphabet, keeping the coding secret, to guarantee measurements without bias. Bags with samples were labeled and separated by tone and brand, to be stored in coded boxes.

Operator called “C” made the measurements. Thickness measurements: box of coded resin discs was opened by an operator who was unaware of the meaning of the coding; a disc was taken out of the bag and using a metal analogue thickness gauge it was measured, recording the thickness in millimeters on the label of the individual bag; The disk was kept in the corresponding bag and this was done for all samples. Subsequently, the thickness data was transferred to an Excel-Office365-version-2016-Microsoft spreadsheet, ordering them according to the bag's coding. No disc thickness other than 1 mm (+/- 0.1 mm) was used in the study.

Color measurements: VITA-Easyshade-V equipment was turned on and connected by Bluetooth to a computer with the VITA-Assist program for data collection. Selected composite resin sample was placed with nitrile gloves on an opaque black background inside a dark chamber, so that there were no external light sources that would alter the measurement, and that allowed to be photographed and/or recorded.

Data measurements were performed, according to the manufacturer's specifications, after calibrating the VITA-Easyshade-V, for each measurement. 7 average color measurements were made (2 on the manufacturer's standard), the average of which gave 1 measurement of values for CIEL a*b and CIEL H*c. This was performed 5 times for each sample, obtaining the data from the computer screen and recording it in spreadsheets Excel-Office365-version-2016-Microsoft (Redmond, Washington, USA).

To calculate the CIE L*a*b (E*) color difference between the enamel shades the following equation was used: ΔE* = {(ΔL*)2 + (Δa*)2 + (Δb*)2}1/2, where Δ are the mathematical differences between L*, a* and b* of the different products in each tone. To define the relationship between the differences of colorimetric ranges and differences in visual color perception, those colorimetric differences greater than 3.3 were considered clinically perceptible differences (Table **1**) [5, 6].

RESULTS

Analysis was carried out according to data obtained on the CIE L*a*b scale in the different types of composite resins on black/blue, with the data analysis computer program Excel-Office365-version-2016-Microsoft. For the statistical analysis in this section, it was taken into consideration that, as the samples were small, 5 measurements were taken from each one, obtaining an average of these data and mean deviations. Then, to measure the effectiveness of the sample, the average deviation from the arithmetic mean is considered, which is defined as the arithmetic mean of the absolute values of the differences between the values of the variable and the arithmetic mean:

$$Dm = 1N\Sigma|xj - \overline{x}|ni$$

The formulas were applied to determine TP and ΔE* and these results were incorporated into a table and were compared and described for each type of resin.

The statistical analysis was performed using the Excel-Office365-version-2016-Microsoft computer

Table 1: Delta E Difference of Perception Scale

ΔE Value Range	Difference/Perception
ΔE less than 1	Color difference is not perceived by the human eye.
ΔE between 1 y 2	Color difference is perceived by an experienced observer.
ΔE between 2 y 3	Obvious difference between reference color and obtained color, but it is acceptable.
ΔE between 3 y 4	Obvious difference between reference color and obtained color, but it does not affect the work.
ΔE between 4 y 5	Obvious difference between reference color and obtained color, at the limit of acceptance.
Greater than 5	Obvious difference between reference color and obtained color, unacceptable.

program. A descriptive study was carried out and then the data were analyzed by the ANOVA test for color groups A2 and A3 separately, the measurement values being compared with the respective CIELab value.

As a descriptive study for color A2, each average obtained reflects the numerical difference with respect to the reference of the CIELab value of color A2, expressed as a delta E value. A lower delta E represents less distance with respect to the color that should ideally be obtained when measuring the composite resin disc [7].

Shapiro-Wilk data distribution normality test shows us a normal distribution of data and, consequently, gives us the possibility of performing a 1-factor ANOVA test to perform the null hypothesis analysis.

1-factor ANOVA test showed a statistically significant difference for the material variable ($p<.001$), meaning that there is a statistically significant difference in Delta E measurements for the different groups of materials.

To analyze which groups differ from others, a Tukey Post-Hoc analysis was carried out.

Glacier has a statistically higher Delta E than Empress Direct, Opallis and Brilliant, but the rest of the groups do not present statistically significant differences in their Delta E.

For descriptive study of color A3, each average obtained reflects the numerical difference with respect to the reference of the CIELab value of color A3, expressed as a delta E value, it should be noted that a lower delta E represents less distance with respect to the color that should ideally be obtained when measuring the composite resin disc [7].

Normality test suggests a normal distribution of data for the groups. It should be noted that for this color one of the calculations was omitted since it appears as an extreme value. Although this value affects the calculation of the FiltekZ350XT group mean, it does not have a major influence on the rest of the statistical test.

The ANOVA statistical test shows us a statistically significant difference between the Materials groups ($p<.001$).

The Post-Hoc test of the analysis shows us that the Glacier composite resin has a higher Delta E than the rest of the resins, being statistically different, followed by Herculite which differs statistically from Empress Direct and FiltekZ350XT, but not so Opalis and Brilliant, which are also statistically equal; and that FiltekZ350XT has the lowest Delta E of the group only being statistically equal to Empress Direct.

Table 2: Result for A2 Enamel Composite Resins

Color Materials A2	Mean Value	Standard Deviation
FiltekZ350XT®	10.98	2.143
Glacier®	14.52	2.876
Empress Direct®	8.39	3.328
Herculite®	9.52	3.822
Opalis®	7.15	1.934
Brilliant®	6.88	2.697

Table 3: Result for A3 Enamel Composite Resins

Color Materials A3	Mean Value	Standard Deviation
FiltekZ350XT®	3.26	0.65
Glacier®	20.15	3.532
Empress Direct®	4.96	0.528
Herculite®	11.17	3.745
Opalis®	7.95	1.961
Brilliant®	6.71	2.691

EmpressDirect composite resin is statistically equal to Opalis and Brilliant resins (Tables **2**-**3**).

DISCUSSION

Several studies have compared the compatibility of composites resins of identical color designation and concluded that there is often poor color compatibility between shade pairs [8, 9].

A study concluded that 75% of shade pairs they tested showed a mismatched color. 8 Other, showed that only a few brands of composite resins matched shades of the corresponding VITA shade guide, 3,4

Studies showed that computer-assisted hue analysis is more accurate and consistent compared to visual method, while spectrophotometers are the most reliable standard for color matching [10].

None of the composite resins evaluated manages to be below the minimum perceptibility threshold. Delta E value of the evaluated composite resins range is 3.33 to 3.7 (minimum values that the human eye can distinguish under normal clinical conditions) [7, 10].

Exception results was FiltekZ350XT composite resin in shade A3, which is below the perceptibility threshold, and it could then be concluded that this is the only composite resin that could be found in relation to the A3 color of the VITA-Classical scale. This results may be due to the optical characteristics of the composite, due to a lower translucency in relation to other composite resins. This could be due to its higher degree of conversion, the nanohybrid particles and nanoclusters, or the type of organic matrix [12, 13].

Other studies carried out using the VITA-Easyshade-Compact spectrophotometer, making color readings of the FiltekZ350 composite resin, have found color differences of composite resin studied and determined that color A2 of the resin studied did not correspond to A2 color of the VITA-Classical scale [14].

Results of this study are consistent with others who concluded that there is a color mismatch when comparing enamel shades of composite resin of all brands alone with VITA-Classical [4].

Regarding the statistical results of the measurement of group of composite resins in shades A2: Glacier has a much higher delta E value. Filtek and Herculite products mark the midpoint in A2 composite resins, which means that they could be used indiscriminately with the other brands of composite resins analyzed without noticing a significant difference in their shades. Everything described above is based on statistical results, considering the delta E parameter of the respective composite resins.

Results demonstrate different natures of composite resin brands, which could be useful in clinical experience, as is the case in both Tables (**A2**-**A3**) where the result of the Post-Hoc test is expressed, in which can be seen that the Opallis and Brilliant show statistically identical delta E values.

In measurements of shade A3, the results obtained from this color scatter much less than the results obtained from color A2. This could be explained because the saturation of the group of composite resins A3 is greater, therefore, the background does not influence the measurements of the samples of this color as much.

Glacier A3 has a statistically higher Delta E than the rest of the composite resin systems, which suggests that the color behavior of these composite resin systems could be associated with a brand consistency, which represents a color that is not only far from its corresponding VITA value, but also from all composite resins A3.

None masked the dark background when used in thicknesses of 0.5-1 mm, suggesting that the CIELab values will be altered by a dark background, for these thicknesses [15]. This is consistent with other studies that affirm that layers with thicknesses less than 2 mm are affected by the color of the background [16-19].

However, it is also true that the optical properties of resins are greatly influenced by factors other than thickness [20-22].

Various authors explained that the L* a* and b* parameters decreased when the records were taken on a black background [23-25]. Indicating that the black background not only influences the luminosity of the restoration, but also the chroma, which is why sometimes in large preparations, they are observed with a grayish color since there is no supporting tooth structure [26-28].

A study pointed out that the EasyShade-V instrument is not suitable for measuring composite samples with the CIE L*a*b* system, because its results are statistically different from those delivered by a laboratory spectrophotometer [29]. The values delivered by EasyShade have much greater differences than those that are clinically acceptable. It is believed that these differences when measuring with Easyshade-V may be due to the fact that maintaining the active tip of the instrument with the resin sample at 90° is very complicated [30].

However, this variable was controlled with the use of a positioner and a dark room, which fulfilled two objectives: keeping the spectrophotometer at an angle of 90° with respect to the measured sample and avoiding external light contamination.

In contrast other study, found that the VITA-Easyshade-V spectrophotometer is the most reliable instrument in both *in vitro* and *in vivo* circumstances [31, 32].

Furthermore, the human eye can detect very small color differences and the range of shades available in shade guides is inadequate, making it impossible to translate results to CIE color specifications [33-35].

This study suggests that specific colorimetric tables be created for each commercial brand, made of the same composite resin.

Finally, it cannot be confirmed that companies manufacturing carries out real quality control of the color they claim to represent. For this study none of the measurements carried out on these composite resin systems meet the minimum acceptable perceptibility parameter.

CONCLUSION

There are significant colorimetric differences in A2 enamel composite resins, with respect to the original color of VITA-Classical, when measured with the VITA-EasyshadeV spectrophotometer.

There are significant colorimetric differences in A3 enamel composite resins, with respect to the original color of VITA-Classical, when measured with the VITA-EasyshadeV spectrophotometer, except for the FiltekZ350XT composite resin.

CONFLICT OF INTEREST STATEMENT

The equipment, measurement and evaluation were managed as loans and/or donations. The research group had no contact with representatives of the brands. The authors declare that there are no conflicts of interest in the conduct of this study.

AUTHORS' CONTRIBUTION

Autor 1 Rodrigo Rubio: Contributed to conception, design, data interpretation, drafted and critically revised the manuscript.

Autor 2 Danilo Giusto: Contributed to design, data acquisition and interpretation, performed all statistical analyses.

Autor 3 Fernanda Hitschfeld: Contributed to design, data acquisition and interpretation, performed all statistical analyses.

Autor 4 Raimundo Sarmiento-Oesterreich: Contributed to design, data acquisition and interpretation, performed all statistical analyses.

Autor 5 * Jaime Sarmiento-Cornejo: Contributed to conception, design, data interpretation, drafted and critically revised the manuscript.

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