ORIGINAL ARTICLE

Color stability of resin composites for orthodontic use

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ABSTRACT

Introduction: *The aim of this in vitro study was to evaluate the interference of three beverages (coffee, Coca-Cola® and red wine) in the color of resin composites: Transbond XT®, Orthocem®, Fill Magic® and Z100®.* ***Methods:*** *The sample was made up of 160 test specimens (n=10), with a total of 40 for each composite. During the experimental period of 28 days, the test specimens were immersed in distilled water and kept in an oven at 37° C. The experimental groups were immersed in coffee, red wine or coca cola, respectively, 5 days a week, for 3 minutes a day. The color variations were quantified, considering the variation expressed in delta E (ΔL*, Δa* and Δb*). The data were statistically analyzed by means of the nonparametric Kruskal Wallis and Dunn tests, considering a level of significance of 5%.* ***Results:*** *No significant differences were verified among the brands ($p>0.05$) for variation in color (ΔE), when they were immersed in the same solution. For the Transbond XT brand, higher variation in color values (ΔE) were observed for the composites immersed in wine ($p<0.05$), followed by coffee and Coca-Cola. For Fill magic, Orthocem and Z100, the composites immersed in coffee or wine showed higher variation in color values.* ***Conclusion:*** *All the composites showed higher variation in color values when immersed in wine and coffee when compared with Coca-Cola and distilled water. The composites of the Transbond XT and Z100 brands showed lower variation in color values than Fill Magic and Orthocem when immersed in Coca-Cola and distilled water.*

Keywords:

Esthetics. Orthodontics. Colorimetry. Resin composites.

INTRODUCTION

Esthetics forms part of day-to-day life in a wide variety of health care areas, and the incessant quest for perfection is shared by both patients and professionals. Orthodontics did not remain far from these concerns, because some esthetic appliances were developed over the course of the years. The use of resin composites in orthodontic treatment has enabled the direct bonding of brackets to tooth enamel, with the quality of the bond and color stability being essential factors in the application of these materials.[1]

In spite of dental composites having advantageous esthetic possibilities,[2] color changes in restorative composites after being exposed to simulated oral environments have been the object of study in researches.[1,3-6] Studies have predicted that esthetic properties may be considerably compromised as a result of these materials becoming discolored. Resin composites are capable of acquiring different degrees of discoloration, and this change of color in the materials results from extrinsic and intrinsic factors.[2]

Among the intrinsic factors is the variation in chemical structure of these materials. At present, the majority of resin composites are activated by light. This action is related to some chemical activation components in the cure formulations. The best known photoinitiator contained in resin material is camphorquinone. Some manufacturers include other photoinitiators, normally with a reduced yellowing effect. Consequently, they have better color stability.[7] The degree of change undergone by the organic matrix of a composite is an essential factor for color stability, as the quantity of monomers converted into polymers during the polymerization procedure is proportional to the stain resistance of the product.[8] Moreover, in the presence of oxygen, this conversion does not occur completely, so that the unconverted monomers results in an unpolymerized layer, susceptible to staining.[9]

Whereas the extrinsic factors involve the shade of resin material used, with the darker types being less subject to absorbing pigments and adsorption or absorption of exogenous substances coming from foods. Dark beverages, such as wine and cola-based soft drinks may cause different degrees of staining in these materials, which vary according to the composition of each of these.[10] Coffee is also particularly known to cause staining of teeth and resins.[11,12]

Pigmentation around ceramic brackets, at the interface between the bracket and tooth enamel, filled with resin to promote bonding - a routine fact observed in clinical practice - was one of the great motivators for conducting this study.

In the literature, there are some researches comparing the properties of composites among them, and also with ionomer cements.[1,4,6] However, contemporary composites that are appearing on the market, especially Orthocem®, Transbond XT® and Fill Magic Orthodontic® have hardly been tested. Therefore, in the present research conducted by an in vitro study, the interference of three beverages (coffee, Coca-Cola® and red wine) and a control liquid (distilled water) in the color of composite resins of the Orthocem®, Transbond XT®, Z100® and Fill Magic Orthodontic® were evaluated.

MATERIAL AND METHODS

The sample was made up of 160 test specimens fabricated of resin composite, with a total of 40 for each composite (n=10).

For fabricating the test specimens, the following resin composites were used: Z100® (3M ESPE, SP, Brazil) in shade A2, Transbond XT® (3M, ESPE, SP, Brazil), Orthocem® (FGM, SP, Brazil), Fill Magic® (COLTENE, SP, Brazil) (Table 1).

The test specimens (6 mm in diameter and 2 mm thick) were fabricated with the aid of a two-piece Teflon matrix. The resin composite was inserted into the matrix in a single increment with the aid of a dual Titanium spatula (Millennium, Golgran, SP, Brazil). After inserting the material, a polyester matrix (KDent, Quimidrol, SC, Brazil) was placed on the surface of the material with a glass slide over it. Then a load of 1

Table 1: Composite Compositions and Manufacturers

PRODUCT	MANUFACTURER	COMPOSITION
Z100® na cor A2	3M ESPE, SP, Brazil	TEGDMA, BisGMA, silanized treated Ceramic, 2-Benzotriazolyl-4-methylphenol; * Fillers containing silica-zirconia; Microhybrid
Transbond XT®	3M, ESPE, SP, Brazil	Organic Matrix: Bis-GMA and TEGDMA Inorganic Part: Silanized silica with 70 to 80% by volume of n-dimethyl benzocaine, hexafluorphosphate, Camphorquinone
Orthocem®	FGM, SP, Brazil	Methacrylic monomers such as BisGMA, TEGDMA and phosphate methacrylate monomers, stabilizer, camphorquinone, co-initiator and nanometric silicon dioxide filler particles.
Fill Magic®	Coltene, SP, Brazil	Bis-GMA, Bis-EMA, UDMA,TEGMA,EDAB,BHT, camphorquinone, filler particles and pigment.

kg was placed on the glass slide (Golgran, SP, Brazil) for 30 s to guarantee that the matrix was filled and that the excess material would exude. After removing the load, the material was light activated with a light polymerizing appliance Emitter A Fit (Schuster, SP, Brazil) in accordance with the manufacturers' indications. After each light activation procedure, the power (600 mW/cm 2) of the appliance was monitored with a radiometer (RD7, Ecel, SP, Brazil).

After light activation, the test specimens were withdrawn from the matrix and one of the surfaces was duly identified to serve as a guide when positioning the specimen on the spectrophotometer to obtain the colorimetric values. Throughout the entire experiments, all the test specimens were stored in distilled water at 37±1°C.

The color readouts were made after the test specimens were fabricated, and on conclusion of the experimental period of 28 days. For color assessment the spectrophotometer model SP62S with Model QA Master I Software (X-Rite Incorporated - Neu-Isenburg Germany) was used, with focal aperture of 4 mm, spherical geometry d/8°, and angle of observation of 10°.

Each test specimen was carefully manipulated by using clinical forceps (Millennium, Golgran, SP, Brazil), to prevent the evaluator from making manual contact with the specimen, which could lead to depositing residues and/or grease on it, and influence the values that were found. The test specimens were also carefully dried with absorbent paper to prevent interference of humidity in the color change values. At the time of readout, the test specimens were placed on a white device, duly prepared, so that the readouts could be taken in the correct position.

The colorimetry appliance emitted a light source with waves ranging from 400 to 700 nm on the object and measured the reflection of this spectrum. For translucent objects, the value of the background color is added to the color value of the object. To standardize the values of these measurements, the test specimens were placed on a block with a white, opaque, background color. The color measurements were obtained by means of using the CIE L* a* b* color system. The ΔE*; that is, the total difference between two color stimuli was calculated by using the following formula:

$$\Delta E^* = \sqrt{}(\Delta L^*) + (\Delta a^*) + (\Delta b^*).$$

The CIE L*a*b* system used three parameters for defining color: lightness, hue and saturation[13]. Lightness represents the degree of brightness and darkness of the object represented by the value of L*, with L* = 100 for the brightest white and L* = 0 for darkest black. The parameters a* e b*, called the chromatic scale (hue), represent red if +a* and green if −a*, yellow if +b* and blue if −b*.[14] Saturation and intensity of the hue are given by the numerical value of a* and b*. The values of ΔL*, Δa*, Δb*, correspond to the difference in the values of L*, a*, b*, respectively, in comparison with the first color readout (baseline/initial).

The test specimens were submersed in a receptacle containing distilled water and after this they were placed in an oven at 37° C, for 28 days.

For the period of 28 days the resin composite discs of the experimental groups were immersed in the coloring solutions for 5 days a week, 3 minutes per day in 250 ml of coffee, 250 ml of red wine and 250 ml of Coca-Cola®. The variations in color in the experimental groups were quantified in the following time intervals: baseline/initial and 28 days after pigmentation.

DATA ANALYSIS

The exploratory analysis showed that the data did not meet the presuppositions of a parametric analysis. Therefore, the non-parametric Kruskal Wallis and Dunn tests were used for making comparisons among the brands and solutions. Analyses were performed with the R software program (R Core Team, 2017, R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. URL) with a level of significance of 5%.

RESULTS

In this experimental study, it was possible to compare the color stability of four composites of different commercial brands (Transbond XT, Fill magic, Orthocem and Z100) used for orthodontic bracket bonding, submitted to experimental pigmentation (coffee, red wine, Coca-Cola and distilled water - control), for the period of 28 days.

In Table 2 we could verify that in the analysis of ΔE no significant differences were observed among the brands, when immersed in the same solution (p>0.05) in 28 days. However, when Transbond XT resin was compared with Fill Magic resin and immersed in Coca-Cola, it showed lower variation in color. In the time interval of 28 days, for immersion in Coca-Cola, the Transbond XT and Z100 resins showed the lowest variation in color values when compared with the other materials.

Table 2: Median (minimum value and maximum value) of delta L, a, b and E considering the solution and commercial brand of composite.

TIME	SOLUTION	COMPOSITE BRAND			
		TRANSBOND	FILL MAGIC	ORTHOCEM	Z100
ΔL	Coffee	-7.86 (-12.04; -6.35) Ab	-10.21 (-14.77; 0.75) Ab	-9.72 (-17.81; -6.74) Ab	-11.35 (-14.20; -8.09) Ac
	Wine	-14.35 (-20.92; -5.27) Bc	-13.34 (-25.14; -9.28) Bc	-9.44 (-13.60; -5.31) Ab	-10.36 (-17.04; -4.90) ABc
	Coca	-4.57 (-5.62; 1.42) Aa	-7.50 (-10.17; -4.79) Ab	-7.08 (-10.01; -5.40) Ab	-5.08 (-7.42; -4.08) Ab
	Control	-0.48 (-3.63; 1.28) Aa	-1.72 (-3.77; 2.88) Aa	-1.70 (-4.15; -0.96) Aa	-0.18 (-2.08; 1.41) Aa
Δa	Coffee	2.87 (1.57; 4.56) Ba	6.01 (0.08; 8.08) Aa	3.46 (2.16; 5.97) ABa	4.23 (2.44; 5.16) ABa
	Wine	3.34 (1.93; 5.09) Ba	6.74 (2.98; 9.04) Aa	4.30 (2.41; 7.73) ABa	1.66 (0.64; 4.24) Cb
	Coca	1.96 (1.53; 3.02) Aab	2.51 (1.27; 2.95) Ab	3.26 (2.36; 4.63) Aa	1.52 (1.27; 1.89) Ab
	Control	0.35 (-0.28; 0.59) Ab	0.64 (-0.07; 1.20) Ab	0.66 (0.02; 1.25) Ab	0.00 (-0.36; 0.29) Ab
Δb	Coffee	3.67 (-5.26; 12.48) Aba	4.62 (-0.18; 10.89) Aa	-0.25 (-5.77; 4.56) Ca	0.72 (-2.58; 6.35) BCa
	Wine	-2.20 (-6.51; 3.29) Ab	-1.98 (-5.34; 2.25) Ab	-6.70 (-9.37; -2.68) Bb	-6.51 (-10.23; -2.69) Bb
	Coca	2.01 (0.51; 9.48) Aa	-0.02 (-6.00; 2.59) ABb	-2.33 (-5.81; 2.41) Ba	0.44 (-0.80; 2.54) ABa
	Control	1.05 (-0.73; 3.27) Aab	-0.62 (-2.42; 3.26) Ab	-1.70 (-4.14; 2.03) Aa	-0.09 (-3.35; 1.79) Aa
ΔE	Coffee	10.55 (7.73; 14.97) Ab	14.00 (6.60; 16.26) Aa	10.72 (7.24; 18.79) Aa	12.14 (8.84; 16.28) Aa
	Wine	15.08 (7.68; 21.75) Aa	15.07 (9.98; 26.36) Aa	11.90 (7.30; 17.56) Aa	12.07 (8.18; 20.32) Aa
	Coca	5.43 (4.29; 10.05) Ac	7.93 (5.48; 10.62) Ab	8.41 (6.30; 12.24) Ab	5.50 (4.35; 7.73) Ab
	Control	1.45 (0.96; 4.89) Ac	2.87 (2.17; 4.64) Ac	2.80 (1.22; 5.96) Ab	1.70 (0.51; 3.39) Ab

Means followed by different letters (capitals in the horizontal, and lower case letters in the vertical comparing solutions within each time interval and brand) differ among them (p≤0.05).

In the evaluation according to solution, both coffee and red wine showed higher color change values, however, for some brands of resin, no difference was shown for Coca-Cola, which showed no significant difference from the control groups for any of the evaluations.

In Table 2, the results of delta L are shown. No significant difference between the brands was observed for the composites immersed in coffee, Coca-Cola and distilled water ($p>0.05$). When immersed in red wine, the composites of the Orthocem brand showed the lowest variation in the value of ΔL (delta minus negative) than those of the Transbond XT and Fill Magic brands ($p<0.05$). For Orthocem and Z100 there was no significant difference between the composites immersed in coffee or red wine ($p>0.05$).

Relative to value Δa, the Transbond XT brand composites showed lower variation in color than those of the Fill Magic brand when immersed in coffee or red wine. Fill Magic brand composites showed higher variations in color value Δa when immersed in coffee or red wine. Whereas for Transbond XT and Orthocem, no significant difference was observed between in coffee, red wine and Coca-Cola ($p>0.05$). The Z100 brand composites immersed in coffee showed the highest variation in color values than those immersed in red wine, Coca-Cola and distilled water ($p<0.05$).

Analysis of the value Δb showed a reduction value when Transbond XT specimens were immersed in red wine, and an increase in value when they were immersed in coffee, Coca-Cola and distilled water. For Fill Magic there was an increase (median of the variation>0) when specimens were immersed in coffee. For Orthocem and Z100 higher variation in values (delta plus negative) in composites immersed in red wine ($p<0.05$).

DISCUSSION

The aim of this experimental in vitro study was to simulate situations that occur in the oral cavity. Therefore, immersion in pigmenting substances for 3 minutes was used, as was done in previous studies.[15] Thus, it was possible to compare the color stability of four composites of different commercial brands (Transbond XT, Fill magic, Orthocem and Z100) used for orthodontic bracket bonding, submitted to experimental pigmentation (coffee, red wine, Coca-Cola and distilled water - control), for the period of 28 days.

The color change of resin composites is related to the type of composite (type of resin matrix and filler particles, size of filler particles) and time of immersion in the solutions.[7,16-18]

For the purpose of verifying changes in color, some reference needs to be used to which to relate the color of the composite before and after exposure to the staining tests.[19] The color of materials may be demonstrated in the form of coordinates to locate a color in a color space. Therefore, the variation in the values of the color coordinates may be considered quantifiers in the color of the material.[13] A Commission Internationale de l'Eclairage (CIE) is an entity recognized as being an authority on the science of light and color.[20] This institution has considered tree color spaces, CIE XYZ, CIE L*C*h and CIE L*a*b* - for the communication and expression of colors.[21] At present, the CIELAB color space is the most appreciated of the uniform color spaces used for evaluating colors. This being so, the CIE color parameters L* a* b* (L*, lightness, a*, chromatic coordinate on the green-red axis; and b*, chromatic coordinate on the yellow-blue axis) may be used to evaluate the optical properties of orthodontic resin composites.[13]

According toe the CIELab Standards of 1968, $\Delta E = 1$ is the smallest difference in color perceived by a trained observer, and $\Delta E \leq 3$, are acceptable differences. According to Tekce et al,[20] the clinically refusal limit of color change is $\Delta E > 3,3$. In this study, we verified that the median of the delta E values exceeded 3.3 in all the coloring liquids in which the composites were immersed, irrespective of the brand of composite tested, with the exception of those immersed in distilled water - the liquid used as control. In the literature, no studies that evaluated composites used for bonding orthodontic accessories were found. However, studies conducted with restorative composites have shown color changes resulting from intrinsic and extrinsic factors.[5,17,18,23] Extrinsic stains are mainly associated with the unstable conditions of the oral cavity. These conditions vary right from deposition of coloring agents present in foods through to factors related to products used by patients to perform oral hygiene.[16]

In the present study red wine was found to have a greater capacity for staining in all the resins tested, throughout the time interval that elapsed. Readouts were taken throughout this time, showing greater variation in the delta E value. Furthermore, coffee was also found to cause intense staining when compared with Coca-Cola®. For Fill magic, Orthocem and Z100, the composites immersed in coffee or wine showed higher variation in color values. The Z100 brand of composite immersed in coffee showed color change comparable with that caused by red wine. Coffee contains yellow coloring constituents with low polarity that may cause deeper staining in resin composite by means of mechanisms of adsorption and absorption.[3,5] With regard to red wine, in addition to its inherent color, it has a physico-chemical effect on the resin composite due to fermentation. There are ascetic acid, propionic acid and lactic acid among its constituents and by-products. These acids are capable of causing superficial softening in restorative resins, influencing their resistance to abrasion, and increasing the chances of staining occurring.[23]

In the present study, there were no significant changes in color in the test specimens stored in distilled water (in the control group) in the different time intervals. This result is in line with the findings in the studies of Manojlovic et al.[18] and Lepri et al.[24], in which they verified that the variation in the colors of resins immersed in water were shown to be imperceptible. Therefore, the absorption of water separately is not responsible for visible chromatic changes.[18]

Moreover, reports have stated that the smaller the filler particles, the higher would be the degree of polymerization shrinkage, water sorption. Greater superficial wear and thermal expansion.[26] According to Lepri et al.[24], resins with a smaller quantity of filler particles, such as those used for bonding orthodontic accessories, have shown lower resistance to staining. However, in the present study Transbond XT® resin was found to undergo color change similar to that of Z100® resin. Certain characteristics, such as hardness, flexural strength, translucence and coefficient of thermal expansion are known to be related to the organic matrix of the resin, while chromatic stability is influenced by the organic matrix. Both the above-mentioned composites had the same organic matrix composition, TEGDMA, BisGMA, and an inorganic part, silanized ceramic, differing in percentage by volume. The Z100 composite has Zirconia/Silica 84.5% by weight and 66% by volume, with a mean particle size of 0.6 micrometers. Whereas Transbond XT® resin contains silanized silica, 70 to 80% by volume n-dimethyl benzocaine, hexafluorphosphate, and camphorquinone.

Moreover, worth emphasizing is that intrinsic factors may cause changes in color stability when these resin materials are aged by exposure to different physico-chemical conditions such as oxidation of the residual monomers, concentration of the initiator and quantities of filler particles.[5,17] However, in this study, the influence of intrinsic factors was not tested, only those coming from the diet were.

Considering that this in vitro study was conducted for 28 days and that orthodontic treatment normally has a longer period of duration, further studies are suggested to evaluate the behavior of these composites over a longer period of time. Nevertheless, the results of the present study simulated a real condition, and may serve to guide orthodontists with regard to the choice of bonding material, and to guide their patients relative to their diet.

CONCLUSION

Within the limitations of this in vitro study, it was concluded that there was no difference among the brands for the composites immersed in red wine, coffee and Coca-Cola. Throughout the course of the study time interval, red wine, followed by coffee, were the beverages with the highest potential for staining in comparison with the tested soft drink. As regards distilled water, used as control, there was no significant difference relative to staining. When immersed in red wine for up to 28 days, the composites of the Orthocem, Transbond XT®, Fill Magic Orthodontic® and Z100® brands, higher variation values (delta plus negative) were observed when the composites were immersed in coffee or red wine, in all the time intervals.

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