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ORIGINAL RESEARCH

The Effect of Different Curing Time Regimens on Immediate Postpolymerization Color Changes of Resin Composites

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ABSTRACT

Aim: Light curing of resin composites may considerably change the color of resin composites. The aim of this study was to evaluate the changing pattern of resin composite's color by different curing times.

Materials and methods: Fifteen, 1 mm-thick, samples of each A_2 shade Clearfill and Filtek P60 composites were prepared. First five samples were cured for 10s (400 mW/cm^2) in each pole of the rectangular samples (right upper, right lower, left lower, left upper plus central zone). Consecutive sets of samples, each consists of five, were irradiated by doubling and tripling the curing time to 20 and 30s. Color change were measured by means of CIE 1976 L*a*b system equation (ΔE) for each digitalized picture of the corresponding sample.

Results: Color of samples was clinically significant changed by increasing the curing time from 10 to 20s and from 20 to 30s for Clearfil (ΔE = 13.86 and 14.11 respectively,) and Filtek P60 (ΔE = 7.68 and 11.66 respectively). The 'b' component change was responsible for the most color alteration confirmed by the linear regression model ($p < 0.001$).

Conclusion: This study revealed the contrasting pattern of resin composite's color change with the different curing times. Our findings support that light curing is accompanied by a higher attained blue chroma and diminished yellowness of resin composites.

Clinical significance: A complete and proper curing of sample resin composites on buccal surface of particular tooth, as a common practice to ensure the maximize concordance composite and tooth color, is reassured according to the considerable differences of undercured and overcured in comparison to normocured composite.

Keywords: CIE system, Color, Chroma, Light cure, Laboratory study, Resin composite.

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INTRODUCTION

Color match of tooth-colored restorative materials is of great concern for both the clinician and patient. During polymerization, double carbon-carbon bonds would be changed into the single-bonded spatial structure which permits elongation and polymerization of the resin composite.[1] It is postulated that the color of resin composites would be changed by the progression of polymerization.[2] Photoinitiator, camphorquinone, would be eventually invisible; hence the yellowness of resin composite would be diminished along with an increased blue chroma.[2,3] Even after the completion of polymerization, resin composites undergo further changes in mouth by hydrophilic volumetric changes, Hydrolysis, stains and alteration of surface smoothness.[1,4,5]

Overly, determination of color changes may be accomplished with either visual method applying a color shade or quantitavely with a device (e.g. colorimetric or spectrophotometric method).[6] Thereafter, calculated color changes may be presented by two well-known systems: Munsell (Nickerson formula) or CIE systems.[7]

Although color stability of resin composites with various energy sources and immersion medias is vastly studied, limited information regarding immediate color change of direct resin composite exists in literature.[8-10] Changing pattern of resin composites with different curing times is not studied yet, as aimed in the present research to be investigated.

MATERIALS AND METHODS

Sample Preparation

Fifteen, 1 mm thick, samples of each A_2-shade Filtek P60 (3M/ESPE, St Paul, MN, USA) and Clearfil (Kuraray,

Tokyo, Japan) resin composites were prepared using a 15×15×1 brass mold. Light curing was accomplished by a quartz-tungsten-halogen (QTC) source by three protocols with a continuous irradiation manner of 400 mW/cm^2 intensity. First five samples were cured 10 s in each pole of the rectangular samples (right upper, right lower, left lower, left upper plus central zone; Fig. 1). Consecutive sets of samples, each consists of five, were irradiated by doubling and tripling the curing time for each quadrant and the central zone to 20 and 30s with the same intensity. Deficient samples with large apparent voids, confirmed by the radiography, were discarded.

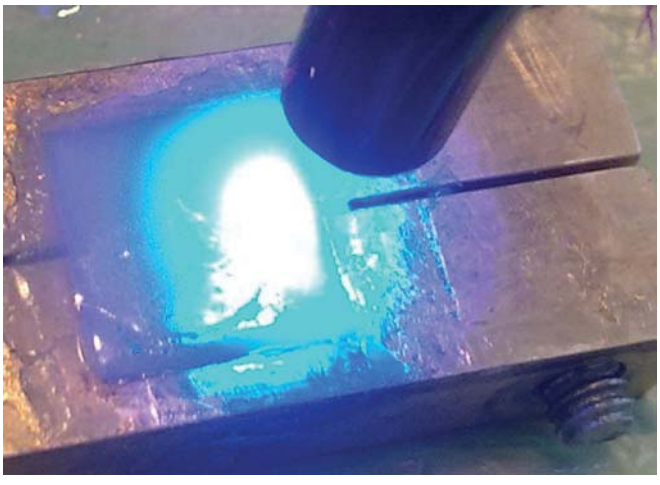

Fig. 1: Each 1 mm thick sampled was cured in five different poles: right upper, right lower, left lower (as shown in this figure), left upper and central zone

Digitalizing and Colorimetric Assessments

Each set of samples were located on a paper and they were digitalized using a 12 megapixel digital camera (Canon, Ixus, Japan) held in position with a holder in suitable distance for a maximum contrast. The process was performed in a dark room with two 60 W light sources from sides toward the samples. Captured pictures were saved in JPEG format.[11]

Thereafter, CIE 1976 L*a*b of each sample was measured with Adobe Photoshop (CS8) software using *eye dropper* option calculated for average obtained from five aforementioned poles. In addition, colorimetric changes (ΔE) were measured using CIE equation: $(\Delta E)=[(\Delta L)^2+(\Delta a)^2+(\Delta b)^2]^{1/2}$. In CIE method 'L' presents brightness, 'a' presents reddish (+a) or greenish (–a) and 'b' displays yellowness (+b) or bluish (–b).

Statistics

Data calculated for L*a*b were tested with a general linear model (GLM) repeated measure ANOVA to detect the pattern of changes over the time. A Mauchly's test of sphericity was used and data was reported with a Greenhouse-Geisser adjustment. Multiple comparisons were performed to compare CIE components between different curing times with Bonferroni adjustment. Moreover, a linear regression model with backward method was build to elucidate by which of 'L' or 'a' or 'b' changes, ΔE is better predictable. A two-tailed $p < 0.05$ was considered statistically significant.

RESULTS

Alterations of CIE components calculated for each sample considering different light-curing regimens are displayed in Table 1 and Figure 2. Overly, 'L' $F(2,10) = 17.63$, $p < 0.001$ eta squared: 0.779, 'a' $F(2,10) = 90.16$, $p < 0.001$ eta squared: 0.948 and 'b' $F(2,10) = 405$, $p < 0.001$, eta squared: 0.992 components were changed statistically significant by increased curing time. Also, 2 by 2 comparisons revealed remarkable changes for 10 to 20s, 20 to 30s and 10 to 30s cured samples in terms of 'L', 'a' and 'b' changes ($p < 0.05$) except for 'L' changes comparing 20 to 10s cured samples ($p = 0.23$). The higher eta squared of 'b' was confirmed by a linear regression model to predict color changes with either 'L' or 'a' or 'b' ($r = 1$, $p < 0.001$).

Table 1: Colorimetric changing trends during incremental curing regimens calculated for *L*a*b* (CIE system)

Exposure intervals	*ΔL*	*Δa*	*Δb*	*ΔE*	
10-20s	↑	↑↑↑	↑	Clearfil	13.86*
				Filtek P60	7.68*
20-30s	↓	↓↓	↓	Clearfil	14.11*
				Filtek P60	11.66*
10-30s	↑	↑	↓	Clearfil	13*
				Filtek P60	3.46

Upright arrows indicate increase and downward arrows indicate decrease; *Clinically significant change

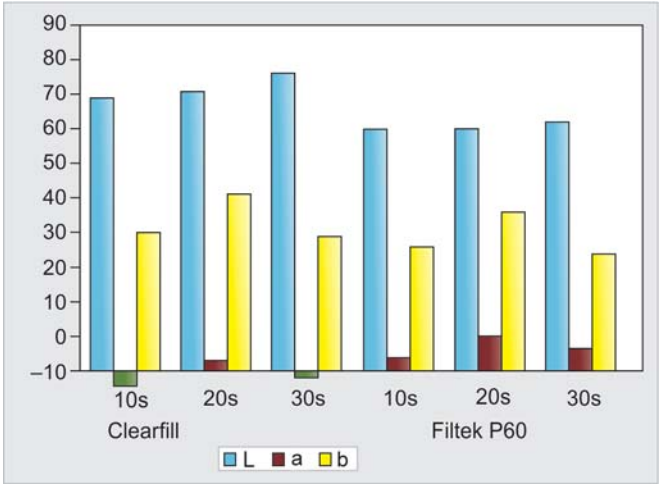

Fig. 2: Changing trend of various CIE L*a*b components with different curing times (10-30s)

DISCUSSION

The present research studied the immediate color changes of Clearfil and Filtek P60 composites after 10 to 30s light curing. Findings elucidated that certain components of color in CIE system may be changed by the progression of polymerization. Moreover, in agreement with Celik et al polymerization induced perceptible color change of both studied resin composites.[12] Final color has slightly reduced yellow chroma. This outcome was in commitment with a previous report. [2] As previously mentioned, after initiation of polymerization, camphorquinone would lose its yellowness.[1] Nevertheless, interesting changes occurred by the midway during polymerization. All CIE color components were increased during 10 to 20s followed by a considerable reduction at 30s. Finally, reddish and brightness were increased and yellowness was reduced. Contra direction of the changes in color elements may be sought elsewhere.

Reviewing kinetic of polymerization, changes of ion viscosity in polymer networks is of interest. Steinhaus et al investigated the real-time polymer ion viscosity (μ) changes during light curing.[13] By dielectric analysis (DEA) method, an initial drop to reach a minimum ion viscosity ($\log \mu_{min}$) was clarified that was followed by a slope increase to reach the saturation level ($\log \mu$). The amount of initial decrease and its duration was correlated with the thickness of resin composite. This is explained by retarding effect of dental composite stabilizer reaction with free radicals.[1] A probable answer to the unique pattern of color changes may be related to reaction of such stabilizers with initiators and free radicals at first when transient gel matrix is been formed. This final color change is not influenced by the shade of resin composite and initial 'b' quantity.[1]

We obtained color changes applying CIE system and Photoshop software. A ΔE of more than 0.5 is visible and is clinically significant, if ΔE is greater than 3.3 score.[7] Photoshop software was used due to its ease of access and performance. In addition, previously it was validated for such purposes.[11,14]

The present research has many limitations. First, immediate postcuring color changes was assessed. Nevertheless, postcuring polymerization may last up to several days.[15] Second, more precise spectrophotometric assay may better reveal the color changes. Third, color instability within mouth is influenced by many other confounders which are not taken into account in this *in vitro* investigation.

A few structural and process modifications are suggested as the following. First, humidity resorbsion is introduced as one certain confounder against the composite color instability. Water may penetrate the polymer matrix and degrade the inner structure in addition to roughening the outer surface.[1] Hence, less hydrophilic monomer like *Bis*-EMA (ethoxylated *Bis*-GMA) may maintain better color stability.[1] Second, photoinitiator, camphorquinone which absorbs at 486 nm, a visible wavelength, has a remarkable esthetic drawback. It possesses yellowness due to its unbleachable chromophore group which rise to unpleasant yellow color to the composite. Accordingly, diluting its concentration with p-octyloxy-phenyl-phenyliodonium hexafluoroantimonate (OPPI), an initiator works at invisible wavelength of 300 to 380 nm, may improve both initial color and color stability.[16] Third, it is noteworthy to mention that overirradiation may lead to polymer matrix destruction and increased yellowness of cured composites. So appropriate wavelength, power and duration are warranted.[10]

A real-time spectrophotometric evaluation along with DEA following of structural changes of resin composites by various curing protocols is recommended for future investigations.

CONCLUSION

Briefly, Clearfil and Filtek P60 resin composites exhibited considerable clinical significant alteration in color elements and visible color during- and postpolymerization with conventional photocuring method. According to our findings, photocuring would cause an increased chroma and a diminished yellowness of resin composites.

CLINICAL SIGNIFICANCE

A common practice is to cure a small piece of resin composite on the buccal surface of tooth to be restored in order to ensure maximized final color match.[12] Hence, importance of complete curing of sample composite on the buccal surface of tooth is reminded. Clinician should be aware of such remarkable color differences, if the sample composite is undercured (e.g. conventional light curing for just 20s), a not uncommon mishaps in routine practice.

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