Color Stability of a Microhybrid Resin Composite Polymerized with LED and QTH Light Curing Units

Original Article

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Abstract

Introduction: Discoloration of resin composites is a common reason for replacement of these restorations. The aim of this study was to evaluate the influence of different light curing devices on color stability of a microhybrid resin composite.

Materials and Methods: 80 disc-shaped specimens (8 mm in diameter, 2-mm height) were fabricated from filtek Z250 resin composite. Specimens were divided into 4 groups (n=20) and cured with LED (Bluephase C5, Valo) or QTH (Astralis7 with two different light intensity) light curing devices. Baseline color of each specimen was measured with a spectrophotometer according to the CIE (L*a*b*) color scale. (CIE L*a*b* is a color measurement system with dimension ***L*** for lightness and ***a*** and ***b*** for the color-opponent dimensions). Each subgroup (n=10) were immersed in tea or artificial saliva for 72h at 37°C. The color values of specimens were remeasured and the color change values (ΔE*ab) were calculated using One-Way ANOVA and Tukey test. A P value of <0.05 was considered significant.

Results: In groups immersed in tea, specimens cured with high power mode of Astralis7 (750mW/cm2), showed the statistically significant lowest color change. There was no statistically significant difference between two types of Light Emitting Diode units.

Conclusion: Conventional halogen light (QTH) with high power mode showed the maximum color stability in tea.

Key words: **•Composite Resin •Surface Properties • Color • Halogen Dental Curing Lights • LED Dental Curing Lights**

Introduction

Resin composites have been widely used since their introduction because of their excellent esthetic properties.[1,2] However, a major disadvantage is their discoloration after prolonged exposure to the oral environment. Unacceptable color match is a primary reason for replacement of composite resin restorations.[3,4]

Resin composite discoloration is multifactorial, including intrinsic discoloration and extrinsic staining.[1, 2,5] External discoloration can be the result of inadequate intensity and duration of the polymerization[6], heat, water[7], food colorants such as red wine, coffee, cola, tea [4,8], smoking habits and bad oral hygiene.[1,9]

Furthermore, the structure of the composite and the characteristics of the filler particles have direct effects on the surface polishing and the susceptibility to extrinsic staining.[4]Intrinsic factors include the composition of the resin matrix, filler loading and particle size distribution, type of photo initiator system and percentage of remaining double carbon bonds.[2]

A correlation between color stability and conversion rate is established, with incomplete polymerized resin composite showing reduced mechanical properties and greater discoloration susceptibility.[4, 10-12]The effectiveness of polymerization is not only dependent upon the chemistry of the material and the filler particle size, but also on the light curing unit used for polymerization, including spectral distribution, irradiation time and intensity.[1,13]

The Quartz tungsten halogen (QTH) lights and light emitting diodes (LEDs) are the currently most used light sources for curing composites.[14]

The QTH lamps have been the standard curing units for several years. QTH light is produced by an electrical current that flows through a fine tungsten filament.[14] Halogen lamps are a low cost technology, that have a broad emission spectrum allowing the polymerization of all known resin composite materials available.

However, they have several drawbacks: a) The final blue light output is less than 1% of the total energy input; b) QTH lamps have a limited lifespan because light filters degrade with time due to the high operating temperatures and proximity to the halogen bulb.[14-16]

The LEDs system, opposed to QTH light, does not produce visible light through the heating of metal filaments, but through mechanical-quantical effects.[14]

The spectral emittance of gallium nitride blue LEDs covers the absorption spectrum of camphorquinone, so that no filters are required in LED light curing units. LEDs are less energy consuming in comparison to QTHs and do not require external cooling. Moreover, LED lamps have a lifetime of several thousands of hours without a significant intensity loss.[14-16] Some light-emitting diode(LED) light-curing units show a similar performance to quartz-tungsten-halogen curing units, while others seem to be less or more efficient. These properties includes: depth of cure(DOC), compressive strength, flexural strength, hardness, and degree of polymerization or double-bond conversion of composite.[13] This acts as an incentive to study the influence of these two types of curing systems on the color stability of composite restorative materials.

The objective of this study was to evaluate the effect of QTH or LED light polymerization on the color stability of a contemporary resin-based restorative material (Filtek Z250) after immersion in two different media.

Materials and Methods

80 disc shaped specimens were prepared using Filtek Z250 resin composite (table 1)

by condensing the material into a silicon mold (8mm in diameter and 2mm thickness).

Resin samples were randomly divided into 4 groups and light cured with different curing units. Two groups of specimens were cured with QTH light (Astralis 7, Ivoclar-Vivadent) under the following modes: Group I (n=20) "high power" at 750 mW/cm^2, Group II (n=20) "low power" at 400 mW/cm^2.

Group III cured by light emitting diodes (LED) (Bluephase C5, IvoclarVivadent) with 500mW/cm2 emitted intensity and Group IV (Valo, Ultradent) with 800 mW/cm^2 emitted intensity. The light-curing units selected for the study are presented in table 2. Because of different light output of light curing units, power density of them was standardized according to the following formula: (table 3)

Power Density (J/Cm²) = Light ty(mW/Cm²) × Exposure Time (S)

Each group was divided into 2 subgroups (n=10) according to the immersion media (tea and artificial saliva). The distance between the light source and specimen was standardized by using a 1mm glass slide. The specimens were polymerized in one step and from one side. The cured specimens were removed from the mold and polished with wet 220-400-600-800 and 1200-grit silicon-carbide(SiC) paper for 30s to standardize the resin surfaces. All the procedures were carried out by the same operator with the same pressure and the same movements.

After immersion in distilled water for 24 h at 37°C, color values of specimens were recorded using a digital spectrophotometer (VITA Easyshade, VITA Zahnfabrik, H.Rauter GmbH & Co. KG, D, Germany). Before measuring the color of the specimens, VITA Easyshade was calibrated using its calibration block, according to the manufacturer's instructions.[17] Color measurements were performed by positioning the specimens on a white background to prevent potential absorption effects on any of color parameters.

The probe tip was placed perpendicular to the surface of the specimens in order to make accurate measurements. Measuring was performed at the center of the resin composite discs and repeated three times.

In each group, a subgroup was stored in tea solution (Yellow label tea; Lipton, London) which was prepared by immersing two prefabricated tea bags (2 x 2 g) into 250 ml of boiling water for two minutes, and the other subgroups were stored in artificial saliva (biotène®, Rancho Dominguez, CA, USA), for 72h at 37° C. Then, the specimens were rinsed under running distilled water for 1 minute. The specimens were then resubmitted to color analysis by the spectrophotometer (Vita easy shade), and the total color change (ΔE) was calculated for each specimen using the equation: $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$ [2, 16] CIE L*a*b* is a color measurement system with dimension L for lightness and a and b for the color-opponent dimensions. Color changes were considered clinically acceptable when $\Delta E < 3.3$.[2, 18, 19]

Statistical analysis

Statistical analysis was conducted employing SPSS software 17.0 (SPSS Software, Munich, Germany). For each material, ΔL*, Δa*, Δb* and ΔE means were subjected to statistical analysis by One-way ANOVA and Tukey's test with the significance level of 5%.

Results

The mean values of color change of the different groups after exposure to the two liquid media for 72 hours are summarized in Table 4 and graphically represented in Graph1. The color change in all four groups was significantly different in tea ($p < 0.05$).

For all groups, the mean value of color change in subgroup B (tea) was significantly higher than the mean value of color change in subgroup A (artificial saliva). For subgroup A, no statistically significant differ-

ences were found in ΔE among the all tested groups ($p>0.05$).

Table 1. Tested resin-based composite

Product	Manufacturer	Shade	Type	content		
				Organic matrix	filler	Particle size
Filtek Z250	3M Espe, St.Paul, USA	A2	Microhybrid	BisGMA,UDMA, Bis-EMA	Zirconia/silica	0.01–3.5µm

Table 2. Light curing units used

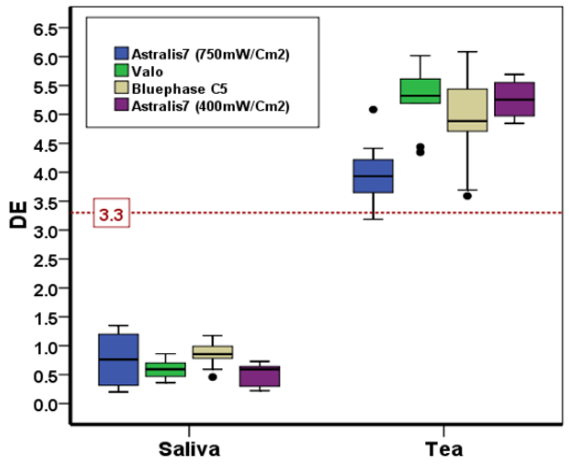
Light curing unit	Type	Wave length	Out put	Manufacture
Bluephase C5	LED	430-490 nm	500 mW/Cm²	IvoclarVivadent
Valo	LED	395-480 nm	800 mW/Cm²	Ultradent
Astralis 7	QTH	400-500 nm	HIP: 750 mW/Cm² LOP: 400 mW/Cm²	IvoclarVivadent

Table 3. Standardization of power density

Light curing unit	Output (mW/Cm²)	Time (Sec)	Power density (J/cm2)
Valo	800	20	16000
Bluephase C5	500	32	16000
Astralis7	400	40	16000
Astralis7	750	22	16500

Table 4. The mean values of color changes (ΔE) of groups cured with different light sources after exposure to different liquid media

Groups	Subgroup A (artificial saliva)	Subgroup B (tea)
Group I (Astralis 7,750mW/cm2)	0.76 ± 0.43	3.98 ± 0.58
Group II (Astralis 7,400mW/cm2)	0.50 ± 0.19	5.28 ± 0.33
Group III (Bluephase C5)	0.85 ± 0.22	4.87 ± 0.81
Group IV (Valo)	0.59 ± 0.17	5.28 ± 0.57
P value	0.57	0.000



Figuer1: Mean values of color change (ΔE)

For subgroup B, the mean value of color change in Group I, was significantly lower than the mean values of color change in Groups II($p<0.001$), III($p<0.019$) and IV($p<0.001$). For subgroup B, there was no statistically significant difference in the mean value of color change in Groups II, III and IV ($p> 0.05$).

Discussion

This study evaluated the effects of different light curing units and staining solutions on the color stability of a micro hybrid composite, filtek Z250.

Color plays an important role in obtaining natural appearance. Discoloration of resin composites may be a major cause for replacement of restorations.[20] The color stability of the resin composites is related to the resin matrix, dimensions of filler particles, degree of polymerization, depth of cure, photo initiators and staining agents.[12,13,21-23]

The degree of conversion plays an essential role in the color stability of resin composites. Incomplete polymerization of the resin composite may cause undesirable properties, such as water absorption and solubility of the unreacted monomers, making it more susceptible to staining.[16, 21]

Discoloration of dental materials can be evaluated by visual or instrumental techniques. The color evaluation by visual comparison may not be a reliable method due to inconsistencies inherent in perception of color and specification of observers. Instrumental techniques include colorimetry, spectrophotometry and digital image analysis. Spectrophotometry has been reported as the most reliable technique in dental material studies.[20, 24, 25]

The VITA Easyshade is a spectrophotometer used in our study. Kim-Pusateri S. et al.[26] reported that VITA Easyshade was the only color measurement instrument, comparing 4 shade-matching devices that had both reliability and accuracy values greater than 90%.

The CIE L*a*b* color system used in this study is a common international method for dental purpose, and it characterizes color by 3 spatial coordinates, L*, a*, b*. L* represents the brightness (value) of a shade, a* represents the amount of red-green color and b* represents the amount of yellow-blue color.[20, 27] In our study, L*, a* and b* were measured by easy shade and the color difference (ΔE) between the color coordinates was obtained using the following equation:

$$\Delta E^* = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

in order to compare values before and after immersion. [3,16] In this study, $\Delta E<3.3$ was considered clinically acceptable, which cannot be detected by human eyes. [2, 18, 19] Our first hypothesis, that discoloration of resin composite does not depend on the type of immersion media, was rejected. In the present study, the Filtek Z250 showed less color change in artificial saliva when compared to tea. Furthermore, the color change values for all groups in saliva have been achieved and clinically acceptable ($\Delta E<3.3$).

There was no statistically significant difference between 4 groups, which is in accordance with other studies.[13, 28, 29] Saliva contains no pigment so its susceptibility to causing discoloration may be due to water sorption of the resin matrix of composites.

The water absorption causes filler–matrix debonding or hydrolytic degradation of the fillers. In addition, it makes micro-crack or interfacial gaps at the interface between filler and matrix, and allows intrinsic discoloration.[20, 27, 30]

Color change values for all groups in tea were greater than 3.3. These values were considered clinically unacceptable. This color change occurred by combination of intrinsic and extrinsic discoloration. Intrinsic discoloration may occur due to penetration of yellow pigments in to them through micro-cracks or interfacial gaps at the interface between filler and matrix. Extrinsic discoloration may be due to adsorption of polar colorants and yellow pigments existing in tea, onto the surface of resin composite materials.[4, 8, 21, 27] Nasim et al.[20], believed that the tannic acid existing in tea may cause discoloration of resin composites.

Our second hypothesis, that color stability of resin composite does not depend on the type of light curing unit, was rejected. Because QTH light curing unit, Astralis7 with 750 W/cm2 intensity, showed the lowest color change ($\Delta E = 3.98 \pm 0.58$). This was in accordance with Tarle et al. [31] that found the highest degree of donversion was achieved with high power mode of Astralis 7, between all curing modes of Astralis 7 and one LED unit.

In comparison to LED units, our finding was in accordance with several studies which observed that the degree of conversion reached with LED curing units is 5–10% lower than conversion values reached with halogen curing units. [31-33] Hence, our finding, that specimens cured with this QTH unit are more color resistant than LEDs, is justifiable.

In comparison to two modes of QTH light curing unit, Astralis 7 with high intensity mode showed less color change than low intensity mode.

Knezević et al.[32] and Tarle et al. [31], have shown that in illumination of resin composite samples with Astralis 7 halogen curing unit, the highest temperature rise was obtained for high intensity mode (which has an intensity of 750 mW/cm^2) compared to the low intensity mode (which has an intensity of 400 mW/cm^2). The results of previous studies show that the higher the degree of conversion, the higher the temperature rise is. And, the temperature rise is higher when the light intensity is higher.[32, 33] Therefore, higher temperature rise might have led to our finding.

Conclusion

Under limitations of this study, these conclusions can be mentioned:

1. Color stability of Filtek Z250 resin composite was clinically unacceptable in tea solution ($\Delta E > 3.3$).
2. Filtek Z250 resin composite cured with high intensity QTH light source (750mw/cm2) showed the highest color stability.

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References

1. Villalta P, Lu H, Okte Z, et al. Effects of staining and bleaching on color change of dental composite resins. J Prosthet Dent 2006; 95(2):137-42.
2. Sarafianou A, Iosifidou S, Papadopoulos T, EliadesG. Color stability and degree of cure of direct composite restoratives after accelerated aging. Oper Dent 2007; 32(4):406-11.
3. Fontes ST, Fernandez MR, Moura CM, Meireless S. Color stability of a nanofill composite: effect of different immersion media. JAppl Oral Sci. 2009; 17(5):388-91
4. Ertas E, Guler AU, Yucel AC, et al. Color stability of resin composites after immersion in different drinks. Dent Mater J 2006; 25(2):371-6.
5. Choi MS, Lee YK, Lim BS, et al. Changes in surface characteristics of dental resin composites after polishing. J Mater Sci Mater Med 2005; 16(4):347-53.
6. Janda R, Roulet JF, Latta M, eta l. Color stability of resin based filling materials after aging when cured with plasma or halogen light. Eur JOral Sci 2005; 113(3):251-7.
7. Vichi A, Ferrari M, Davidson CL. Color and opacity variations in three different resin-based composite products after water aging.Dent. Mate 2004; 20(6):530-53.
8. Bagheri R, Burrow MF, Tyas M. Influence of food-simulating solutions and surface finish on susceptibility to staining of aesthetic restorative materials. J Dent 2005; 33(5):389-98.
9. Hasani Tabatabaei M, Yassini E, MoradianS, Elmamooz N. Color stability of dental composite materials af ter exposure to staining solutions: a spectrophotometer analysis. JIDA 2009; 21(1):69-78. Persian.
10. Janda R, Roulet JF, Kaminsky M, et al. Color stability of resin matrix restorative materials as a function of the method of light activation. Eur J Oral Sci 2004; 112(3):280-285.
11. Micali B, Basting RT. Effectiveness of composite resin polymerization using light-emitting diodes (LEDs) or halogen-based light-curing units. Braz Oral Res 2004; 18:266-70.
12. Rüttermann S, Suyoun K, Raab WH, Janda R. Effect of exposure time on the color stability of resin-based restorative materials when polymerized with quartz-tungsten halogen and LED light. Clin Oral Investig 2010 ;14(5):599-605.
13. Domingos PA, Garcia PP, Oliveira AL, Palma-DibbRG. Composite resin color stability: influence of light sources and immersion media. J Appl Oral Sci. 2011; 19(3):204-11.
14. Krämer N, Lohbauer U, García-Godoy F, Frankenberger R. Light curing of resin-based composites in the LED era. Am J Dent 2008; 21(3):135-42.
15. Janda R, Roulet JF, Kaminsky M, et al. Color stability of resin matrix restorative materials as a function of the method of light activation. Eur J Oral Sci 2004; 112: 280-285.
16. Pires-de-Souza Fde C, Garcia Lda F, Hamida HM, Casemiro LA. Color stability of composites subjected to accelerated aging after curing using either a halogen or a light emitting diode source. Braz Dent J 2007; 18(2):119-23.
17. Ergücü Z, Türkün LS, Aladag A. Color stability of nanocomposites polished with one-step systems. Oper Dent 2008; 33(4):413-20.
18. Sarafianou A, Iosifidou S, Papadopoulos T, Eliades G. Color stability and degree of cure of direct composite restoratives after accelerated aging. Oper Dent 2007; 32(4):406-11.
19. Celik C, Yüzügüllü B, Erkut S, Yazici AR. Effect of bleaching on staining susceptibility of resin composite restorative materials. J EsthetRestor Dent 2009; 21(6):407-14.
20. Nasim I, Neelakantan P, Sujeer R, Subbarao CV. Color stability of microfilled, microhybrid and nanocomposite resins: an in vitro study. J Dent 2010; 38Suppl 2:e137-42

21. Yazici AR, CelikC, DayangaçB, OzgünaltayG. The effect of curing units and staining solutions on the color stability of resin composites. Oper Dent 2007; 32(6):616-22.

22. Janda R, Roulet JF, Latta M, et al. Color stability of resin-based filling materials after aging when cured with plasma or halogen light. Eur J Oral Sci 2005; 113(3):251-7.

23. Janda R, Roulet JF, Kaminsky M, et al.Color stability of resin matrix restorative materials as a function of the method of light activation. Eur J Oral Sci 2004; 112(3):280-5.

24. Brook AH, Smith RN, Lath DJ. The clinical measurement of tooth color and stain. Int Dent J 2007; 57:324–30.

25. Liberman R, Combe EC, Piddock V, et al. Development and assessment of an objective method of color change measurement for acrylic denture base resins. JOral Rehabil 1995; 22:445–9.

26. Kim-Pusateri S, Brewer JD, Davis EL, Wee AG. Reliability and accuracy of fourdentalshade-matchingdevices. J Prosthet Dent 2009; 101(3):193-9.

27. Ertaş E, Güler AU, Yücel AC, et al. Colorstability of resincomposite safterimmersion in different drinks. Dent Mater J 2006; 25(2):371-6.

28. Lee YK, Lim BS, Powers JM. Color changes of dental resin composites by a salivary enzyme. J Biomed Mater Res B ApplBiomater 2004; 70(1):66-72.

29. Domingos PA, Garcia PP, Oliveira AL, Palma-Dibb RG. Composite resincolorstability: influence of light sources and immersion media. J Appl Oral Sci 2011; 19(3): 204-11.

30. Barutcigil Ç, Yıldız M. Intrinsic and extrinsicdiscoloration of dimethacrylate and silorane based composites. J Dent 2012 Jul; 40Suppl 1: e57-63

31. Tarle Z, Knezevic A, Demoli N, et al. Comparison of composite curing parameters: effects of light source and curing mode on conversion, temperature rise and polymerization shrinkage. Oper Dent. 2006;31(2):219-26.

32. Knezević A, Tarle Z, Meniga A, et al. Influence of light intensity from different curing units upon composite temperature rise. J Oral Rehabil 2005; 32(5):362-7.

33. Knežević A, Tarle Z, Meniga A, et al. Degree of conversion and temperature rise during polymerization of composite resin samples with blue diodes. J Oral Rehabil 2001; 28: 586–591.