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Effect of the difference in spectral outputs of the single and dual-peak LEDs on the microhardness and the color stability of resin composites

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ABSTRACT

Objectives: To determine the effect of the spectral output of single and dual-peak light emitting diode (LED) curing lights on the microhardness and color stability of commercial resin composites formulated with camphorquinone and alternative photoinitiators in combination.

Materials and Methods: Three light-polymerized resin composites (Z100 (3M ESPE), Tetric Ceram (Ivoclar Vivadent) and Aelite LS Posterior (Bisco)) with different photoinitiator systems were used. The resin composites were packed into a Teflon mold (8 mm diameter and 2 mm thickness) on a cover glass. After packing the composites, they were light cured with single-peak and dual-peak LEDs. The Knoop microhardness (KHN) and color difference (ΔE) for 30 days were measured. The data was analyzed statistically using a student's *t*-test ($p < 0.05$).

Results: All resin composites showed improved microhardness when a third-generation dual-peak LED light was used. The color stability was also higher for all resin composites with dual-peak LEDs. However, there was a significant difference only for Aelite LS Posterior.

Conclusions: The dual-peak LEDs have a beneficial effect on the microhardness and color stability of resin composites formulated with a combination of camphorquinone and alternative photoinitiators. [J Kor Acad Cons Dent 2011;36(2):108-113.]

Key words: Alternative photoinitiators; Camphorquinone; Color stability; Dual-peak light emitting diode (LED); Microhardness; Spectral outputs

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INTRODUCTION

The degree of resin polymerization achieved during a restoration placement is a major factor in the success and predictability of resin composite restorations. The polymerization of resin composite depends on many intrinsic conditions, such as the type of the photoinitiator, composition of filler particles, shade and degree of translucency of the materials. In addition, the effective spectral output and irradiance of the light curing unit are needed for adequate polymerization.[1,2]

Camphorquinone (CQ) has been largely used as a photoinitiator since the introduction of visible-light activated resin composites. However, alternative photoinitiators have been studied because the intense

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yellow hue of CQ can affect resin esthetics.[3-5] Compounds derived from acylphosphine oxides (MAPO-Lucirin TPO and BAPO-Irgacure 819) and phenyl-propanedione (PPD) have been suggested as photoinitiators for applications in adhesives and resin composites to reduce the photoyellowing effect.[3,4,6]

Unlike the conventional composite resins (which contain CQ only), the absorption peak of newly developed composite resins (which contain an alternative photoinitiator) is in the near Ultraviolet (UV) region and extends slightly into the visible wavelengths (< 420 nm).[3] However, to date, the conventional light emitting diode (LED) lights currently used have been unsuitable for curing these alternative initiators due to the narrow emission spectrum. These LED lights have a peak wavelength in the 470 nm range, which is ideal for curing traditional resin composite using CQ as an activator. Therefore, the degree of conversion of these resins will be inadequate if a single peak LED light is used,[7] which may result in decreased physical properties,[8] color stability[9] and biocompatibility.[8,10] The degree of monomer conversion of resin composites can be measured by indirect methods, such as surface hardness test[11] and intrinsic color shifting test.[12,13]

Dual peak and polywave third generation LED curing lights have been introduced to overcome this problem. These LEDs deliver light in both the 450-470 nm and 395-410 nm ranges. The manufacturers claim that the new polywave LED is suitable for different photoinitiators and can be used with any dental materials. However, few studies have evaluated the performance of single-and dual-peak LEDs on the market with commercial resin composites. Furthermore, previous reports[14-16] showed that resin composites that use alternative photoinitiators were inadequately polymerized using single-peak LED curing lights.

Therefore, the present study examined the effect of the difference in spectral output of single-and dual-peak LEDs on the microhardness and color stability of commercial resin composites formulated with CQ and alternative photoinitiators (e.g., PPD and lucirin TPO) in combination.

MATERIALS AND METHODS

In this study, three light-polymerized resin composites with different photoinitiator systems were used. Z100 (3M ESPE, St Paul, MN, USA) use only CQ as the photoinitiator, whereas Tetric Ceram (Ivoclar Vivadent, Schaan, Liechtenstein) and Aelite LS Posterior (Bisco, Schaumburg, IL, USA) appear to use two photoinitiator systems, most likely CQ and an alternative initiator (e.g., PPD or lucirin TPO).[17] All resin composites were packed into a Teflon mold (8 mm diameter and 2 mm thickness) on a cover glass. After packing the composites, they were light cured with the single-peak LEDs (Bluephase, Ivoclar Vivadent, Amherst, NY, USA) and dual-peak LEDs (Bluephase G2, Ivoclar Vivadent) to an equivalent energy density (Table 1).

1. Knoop microhardness (KHN) measurement

After light curing, the specimens (n = 5) were stored in the dark at 37℃ with 100% relative humidity for 24 hours. The Knoop microhardness was measured at the top and bottom composite surfaces using a Knoop hardness Tester (MMT-7, MATSUZAWA, Tokyo, Japan). The Knoop diamond indenter applied a 25 g load for 15 seconds at three points, all within 1 mm of the center of the composites. For each surface, a total of 15 hardness recordings were made and the mean was calculated.

Table 1. The light curing units (LCUs) used in this study

LCUs	Manufacturer	Irradiance (mW/cm^2)	Irradiation time (sec)	Energy density (J/cm)
Bluephase	Ivoclar Vivadent Schaan, Liechtenstein	960	40	38.4
Bluephase G2	Ivoclar Vivadent Schaan, Liechtenstein	1,160	33	38.3

LCUs, light curing units.

2. Color difference (ΔE) measurement

The specimens (n = 5) were stored in the dark at room temperature for 24 hours. The measurements were made according to CIE L*a*b* color scale relative to the CIE standard illuminant D65 over a white background on a reflection spectrophotometer (CM-3600d, Minolta, Tokyo, Japan) with specular component excluded (SCE) geometry. The illuminating and viewing configuration was CIE diffuse/8° geometry.

After the measurements, the samples were immersed for 30 days in a water bath at 60℃. After immersion, the color measurements were performed again under the same conditions using the same procedures.

By applying the formula, $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$, it was possible to calculate ΔE and compare the values before and after the aging treatment.

3. Statistical analysis

The student's *t*-test was used to analyze the differences in the KHN values and ΔE values achieved with the single- and dual-peak LEDs for all resin composites ($p = 0.05$).

RESULTS

Tables 2 and 3 show the means and standard deviations of the KHNs at the top and bottom surfaces of the resin composites with the single-and dual-peak LEDs. The student's *t*-test indicated significant differences in mean hardness achieved with the single- and dual-peak LEDs for all resin composites tested ($p < 0.05$). The microhardness was higher for all materials cured with the dual-peak LED. The difference was greatest for Aelite LS Posterior, followed by Tetric Ceram and Z100. The microhardness was lower at the bottom than at the top for all composites tested, particularly for Aelite LS Posterior.

Table 4 lists the difference in the color after 1 month of water aging. All resin composite showed a certain degree of discoloration due to aging in water. The color stability between products was different. The student's *t*-test showed a significantly different color change between the single- and dual-peak LEDs for Aelite LS Posterior ($p < 0.05$). However, there was no significant difference between the LEDs for Z100 and Tetric Ceram.

Table 2. Means ± SDs of KHNs for each material at the top surface

Resin composite	Single-peak	Dual-peak	Student *t*-test *p*-value
Filtek Z100	97.77 ± 4.30	104.15 ± 4.98	$p < 0.05$
Tetric Ceram	33.01 ± 3.16	44.45 ± 2.59	$p < 0.05$
Aelite LS Posterior	53.73 ± 6.00	94.76 ± 5.41	$p < 0.05$

SD, standard deviation; KHN, Knoop hardness number.

Table 3. Means ± SDs of KHNs for each material at the bottom surface

Resin composite	Single-peak	Dual-peak	Student *t*-test *p*-value
Filtek Z100	81.79 ± 4.58	91.46 ± 3.68	$p < 0.05$
Tetric Ceram	31.37 ± 2.70	39.82 ± 3.65	$p < 0.05$
Aelite LS Posterior	32.65 ± 3.01	53.40 ± 7.85	$p < 0.05$

SD, standard deviation; KHN, Knoop hardness number.

Table 4. Difference in color (ΔE) after 1 month of water aging

Resin composite	Single-peak	Dual-peak	Student *t*-test *p*-value
Filtek Z100	1.52 ± 0.26	0.94 ± 0.52	$p > 0.05$
Tetric Ceram	2.15 ± 0.45	1.44 ± 0.63	$p > 0.05$
Aelite LS Posterior	1.23 ± 0.40	0.62 ± 0.25	$p < 0.05$

DISCUSSION

To produce a sufficient amount of free radicals for adequate polymerization, resin composites must receive sufficient total energy in the appropriate wavelength range.[18] The polymerization process may be adversely affected if the LCU does not emit enough light at the wavelengths absorbed by the photoinitiators,[17] which may result in reduced hardness,[8] decreased biocompatibility[8,10] and decreased color stability.[9]

Most traditional LED curing lights have a single peak wavelength in the 470 nm range, which is ideal for curing resin composites using CQ as a photoinitiator. However, some commercial composites employ alternative photoinitiators, which respond to wavelengths < 420 nm. Therefore, these resin composites might have incompatibility problems with single-peak LED curing light.[15,16] Accordingly, it is important to determine the effect of the difference in spectral output of the LEDs on the polymerization of resin composites initiated with CQ and alternative photoinitiators in combination.

In this study, all resin composites showed improved microhardness when a third-generation dual peak LED light was used compared to those cured with a single-peak LED cuing light. This may be because the dual-peak LED curing lights deliver light in both the 450-470 nm and the 395-410 nm ranges. With the additional output in the 395-410 nm range, the dual-peak LED curing lights polymerize resins to a greater extent than the single-peak LED curing lights at similar irradiance.[15,16] The increase in microhardness with the dual-peak LEDs using Tetric Ceram and Aelite LS Posterior, which appear to employ an alternative photoinitiator, was lower at the bottom surface than at the top surface. This suggests that the shorter wavelengths needed to activate the alternative photoinitiator in these resins did not reach a depth of 2 mm. This is probably due to Rayleigh scattering of light. Shorter wavelengths are scattered much more than longer wavelengths and may not reach the bottom of the restoration.[19] The intrinsic color change of resin composites is resulted from the alteration of resin matrix as well as the interface between the matrix and fillers.[20] In addition, the degree of conversion was reported to correlate with the discoloration.[9]

Three different intervals were used to distinguish the color differences because the ability of the human eye to appreciate the differences in color differs from individual to individual. ΔE values < 1 were regarded as undetectable by the human eye. Values of $1 < \Delta E < 3.3$ were considered detectable by skilled operators but clinically acceptable, whereas ΔE values > 3.3 were considered detectable by non-skilled persons and were clinically unacceptable for that reason.[21]

All resin composites tested in this study were within this limit when $\Delta E < 3.3$ was used as the clinically acceptable standard. In this study, the color stability was higher for all resin composites cured with the dual-peak LEDs. However, only Aelite LS Posterior showed a significant difference. This can be explained by the greater polymerization of the resin composites with the dual-peak LEDs.

This study had some limitations. The type and amount of alternative photoinitiators included in resin composites tested were not known precisely because manufacturers considered it to be commercially sensitive. Therefore, further studies will be needed to determine the performance of single-and dual-peak LEDs on experimental resins formulated with different concentrations and ratios of CQ and alternative photoinitiators.

Under the conditions of the current study, it can be concluded that the dual-peak LEDs produce significantly beneficial effect on the microhardness and color stability of resin composites formulated with CQ and alternative photoinitiators in combination.

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국문초록

Single-peak LED와 dual-peak LED의 출력 파장 차이가 복합 레진 미세 경도와 색 안정성에 미치는 영향

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연구목적: 여러 광개시제 시스템에 의해 활성화되는 복합 레진을 기존의 single-peak LED와 최신의 dual-peak LED로 광중합하였을 때의 누프 미세 경도와 수중 보관 후의 색 안정성 차이를 알아보기 위한 것이다.

연구 재료 및 방법: Camphorquinone이 광개시제로 포함되어 있는 Z100과 다른 광개시제가 포함되어 있는 것으로 알려진 Tetric Ceram과 Aelite LS Posterior를 유리판 위에서 테플론 주형(직경 8 mm, 두께 2 mm) 내로 충전하고, single-peak LED와 dual-peak LED로 광중합하였다. 중합 후 누프 미세 경도를 측정하였고 한 달 후 색 변화를 측정하였다. 광중합기간의 미세 경도와 색 변화 차이를 student *t*-test로 분석하였다.

결과: 모든 레진에서 dual-peak LED로 광중합하였을 때 미세 경도가 높게 나타났다. 색 안정성 역시 dual-peak LED로 광중합하였을 때 높게 나타났으나 Aelite LS Posterior에서만 통계학적으로 유의한 차이가 있었다.

결론: 다른 광개시제가 포함되어 있는 복합 레진을 dual-peak LED로 광중합한 경우 미세 경도와 색 안정성에 있어서 더 좋은 결과를 얻을 수 있었다.

주요단어: 다른 광개시제; 미세 경도; 색 안정성; 출력 파장; Camphorquinone; Dual-peak light emitting diode (LED)