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다양한 광원에 의한 광중합형 수복물질의 미세경도에 관한 연구

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국문초록

이번 연구의 목적은 청색광을 방출하는 다이오드(LED) 광중합기(FreeLight2, L.E.Demetron I, Ultra-Lume 5)가 3가지의 레진재료들 (Z250, Point 4, Dyract AP)의 미세경도에 미치는 영향을 평가하고 그들의 최적 중합시간을 찾는 것이다. 표본들은 각각의 복합체에 대하여 아크릴릭 몰드(2.0mm×3mm)를 사용하여 만들었다. 모든 표본들은 평평한 유리판위에 Mylar strip을 위치시킨후 제작되었다. 몰드에 복합체가 위치된 후 또다른 Mylar strip으로 덮고 유리판으로 가볍게 압력을 가하였다. 광조사 시간은 Elipar TriLight은 40초, Elipar FreeLight 2, L.E.Demetron I, Ultra-Lume 5는 각각 5, 10 , 20, 40초씩으로 하였으며 평균 경도값은 각각의 그룹에서 상층과 하층을 사용하여 계산했다. 결과의 통계적 유의성을 위해 ANOVA 와 Sheffe's test를 사용하였다. FreeLight 2, Ultra-Lume 5, and L.E.Demetron I는 대조군인 할로겐 광중합 40초에 비교하여 Point 4를 20초에 중합시킬수 있었다. FreeLight 2 and L.E.Demetron I는 대조군인 20초의 할로겐 광중합에 비교하여 Z250을 10초에 중합시킬수 있었다. FreeLight 2와 L.E.Demetron I는 대조군인 40초의 할로겐 광중합에 비교하여 Dyract AP를 10초에 중합시킬수 있었다.

이번 연구에서 사용된 LED 광중합기는 통상적으로 이용되는 할로겐 광중합기와 비교시 절반이하의 조사시간으로도 적절한 미세 경도를 얻을 수 있었다.

주요어 : 복합레진, 할로겐 광중합, 미세경도

Ⅰ. Introduction

Dental composites are an important class of material widely employed in restorative procedures. In recent years, the popularity of esthetic tooth-colored restorations has promoted a rapidly increasing use of resins. Methods and devices to prepare and cure resins have evolved concurrently, passing from chemically cured resins to the modern form of light curing. Because the polymerization of light-cured resins depends mainly on the characteristics and type of the irradiation source used, one method to achieve better final restoration properties is through the improvement of the curing unit. In this regard, new types of light sources need to be tested to verify their viability for clinical application.

Over the past few years, the industry has focused on reducing the resin curing time by using stronger curing lights and/or altering resin composition and photoinitiator concentration[1-6]. The impacts of the new devices and new composite formulations, however, are complex and not yet fully understood[7].

Despite the popularity of halogen bulb technology, it has several shortcomings. The halogen bulb gener-

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ates high heat, which degrades the bulb's components over time[8,9]. Therefore, halogen bulbs have a limited effective lifetime of approximately 100 hours. Research has demonstrated that irradiance values of at least 300mW/cm^2 were necessary to adequately cure a 2-millimeter-thick specimen of resin-based composite[10,11]. Rueggeberg et al[10] recommended using an irradiance of at least 400mW/cm^2 for 60 seconds to cure a 1-mm-thick sample of resin-based composite.

Additional research has demonstrated that resin-based composite filler size also may complicate polymerization. Microfilled resin-based composites have been shown to require more irradiance than hybrid composites[12,13]. Leonard et al[14] revealed that microfilled composites required twice the irradiance that hybrid composites did. To overcome the shortenings of halogen-bulb, Mills et al[9] proposed using visible LCUs using solid-state light-emitting diode, or LED, technology in 1995 to polymerize light-activated dental materials. Thereafter, the first light emitting diode(LED) light curing units(LCUs) for the light polymerization of dental restorative materials were introduced to the market in 2001.

The main advantages of LEDs compared to halogen bulbs are the constant light output in power and spectra, as well as their longer life expectancy and higher efficiency in converting energy to light. The latter advantages make small, cordless LED LCUs possible, which are reliable in their power and spectral output and do not need a cooling fan. The disadvantage of blue LED is the lower power output per single LED, which makes an array of many LEDs necessary, ideally concentrated on a small area.

Light curing units(LCUs) for polymerization of oral biomaterials in dentistry using halogen bulbs are likely to be replaced in the near future by LCUs using light emitting diodes(LEDs). Studies have shown that powerful LED LCUs have the potential to replace conventional halogen LCUs[8,9,15-19].

However, studies have also shown that LED LCUs with relatively low irradiances are sold on market, which may result in insufficiently cured composites and, therefore, inferior mechanical properties of the restorations[15,20-24].

Currently, there is limited published data on newer curing technologies, such as high output InGaN light emitting diode(LED) curing lights.

The purpose of this study was to evaluate the effects of blue LED LCUs on the microhardness of three resin composites and to determine their optimal curing time.

Ⅱ. Materials and methods

A cylindrical acrylic mold with a diameter of 3mm and a depth of 2mm was prepared. A clear Mylar strip was placed on top of the glass plate, and an acrylic hole was placed over this Mylar strip. Photo-activated resin composites(shade A3) were then packed into the hole and another Mylar strip placed on the top of the composite. The composite was then irradiated in bulk from the top using various curing lights. In the present study, two types of restorative materials, namely composites Point 4 and Z250, and a polyacid modified composite resin, Dyract AP, were selected, and curing was conducted using a conventional halogen unit, one high intensity halogen unit, and three light emitting diode(LED) units. The restorative materials and the curing units used in this study are listed in Table 1 and 2.

Dyract AP

Also given is the output of the three curing units. The output of all curing lights were measured by Laser Power Meter(Power Max 600, Molectron, USA)

Table 1. Light-activated materials used in this study

Composite	Manufacturer	Filler (by volume)	Filler particle size (㎛)
Point 4	SDS/Kerr, USA	57%	0.4 average
Z250	3M Dental Products, USA	60%	0.6 average
Dyract AP	Densply, Germany	49%	0.8 average

Table 2. Light curing units used in this study

Curing light	Manufacturer	Curing time	Light intensity (mW/cm²)
Elipar TriLight	3M ESPE, USA	40 s	700
L.E.Demetron I	SDS/Kerr, USA	10, 20, 40 s	1200
Elipar FreeLight 2	3M ESPE, USA	10, 20, 40 s	1100
Ultra- Lume 5	Ultradent, UT	10, 20, 40 s	1250

and curing light meter(Rolence Enterprise Inc., Chungli, Taiwan). The times of irradiation were as follows: Elipar TriLight, 40s; Elipar FreeLight 2, L.E.Demetron I, and Ultra-Lume 5, 10s, 20s, 40s, respectively. We used 40 seconds with a halogen light as the control in the case of Point 4 and Dyract AP, and 20 seconds in the case of Z250.

Ten specimens were made for each combination of light source and composite: a total of 270 specimens. Samples were kept in a dark area at room temperature. Twenty-four hours later we made hardness indentations with a Vickers hardness tester (Fm-7, Future-tech Corp, Japan) using a 200g load and a dwell time of 10 seconds. We measured the top and bottom surfaces of each specimen four times each, then calculated mean hardness values for both surfaces for each of the subgroups. To ascertain the percentage depth of cure, we divided the bottom hardness values by the top hardness values and multiplied the result by 100. Mean hardness values were calculated at the top and bottom for each group. One-way analysis of variance(ANOVA) was used to test the effect of the LCUs, and post-hoc Scheffe' s multiple comparison intervals with the value of statistical significance set at p=0.05. The software used was SPSS 12.0.

Ⅲ. Results

Vickers hardness number(VHN) at the top and the bottom of the 2mm thick samples of a dental composite, obtained 24 hours after exposure using a halogen curing unit and the three LED curing units. Data for microhardness, expressed as VHN for the top/bottom surfaces, and the hardness ratio are shown in Tables 3 to 5. Figures 1 to 3 shows the mean VHN of the top and bottom surfaces according to the various curing lights and composite resins.

Point 4

When compared to the control(TriLight 40s) on the top surfaces, FreeLight 2 showed lower hardness values but no statistically significance for 10-seconds, whereas it showed hardness equivalent to that achieved with the control for 20-seconds, and statistically higher hardness values for 40-seconds, respectively($p<0.05$). On the bottom surfaces, there were no significant differences for 10 and 20 seconds between the two units, whereas FreeLight 2 showed higher hardness values for 40-seconds than the control($p<0.01$).

Hardness values at 10-seconds from the top irradiated surface for Ultra-Lume 5 unit was significantly lower than the control, whereas there were no differences at 20- and 40-second exposure between the two units. On the bottom surface, it showed no difference at 10-seconds and higher mean values thanthe control at 20- and 40-second exposures, and there were no statistically significant differences between the two units. In the case of a L.E.Demetron I, the hardness values of the top surfaces were significantly lower than the control($p<0.01$), but there was no statistically significant difference for the bottom surface for 10-, 20-, and 40-seconds, respectively.

The hardness ratio of the top/bottom surfaces were as follows: with Point 4/ TriLight the bottom/top ratio was 89% at 40-seconds; with Point 4/FreeLight 2, the bottom/top ratio was 90%, 94%, and 95%, at 10-, 20-, 40-seconds, respectively; with Point 4/ L.E.Demetron I it was 90%, 94%, and 95%; with Pont4/Ultra-Lume 5 it was 90%, 95%, and 95% (Table 3, Fig. 1).

Z250

There was no significant difference in hardness values of the top and bottom surface hardness between the FreeLight 2 and the control(TriLight 20) at 10- and 20 seconds. Ultra-Lume 5 showed no significant difference for both surfaces compared to the control at 10- and 20-seconds, with the exception of the 10-second bottom surface, which yielded lower values statistically. In the case of L.E.Demetron I, the hardness values of the top surfaces at 10-seconds were significantly lower than the control, whereas there was no statistically significant difference for the bottom surface at 10-seconds, or for both surfaces at 20-seconds.

The hardness ratio of the top/bottom surfaces were as follows: with Z250/TriLight, the bottom/top ratio was 95% at 20-seconds; with Z250/FreeLight 2, the bottom/top ratio was 95% and 96% at 10-, 20-seconds, respectively; with Z250/L.E.Demetron I it was 97% and 97%; with Z250/Ultra-Lume 5 it was 94% and 96%(Table 4, Fig. 2).

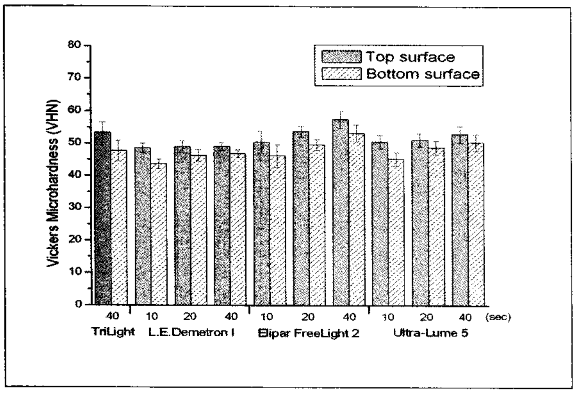

Fig. 1. Vickers microhardness of Point 4 using different curing lights.

Table 3. Microhardness (mean and standard deviation) of Point 4 exposed to four different light sources

Light source	Time used (seconds)	Top surface (VHN)	Bottom surface (VHN)	Hardness ratio (Bottom/Top)
Elipar TriLight	40	53.37(3.17)^{bdf}	47.71(5.29)^{hij}	0.89(0.06)
L.E.Demetron I	10	48.61(1.47)^{a}	43.64(2.03)^{h}	0.90(0.05)
	20	48.96(1.84)^{c}	46.22(2.76)^{i}	0.94(0.05)
	40	49.08(1.24)^{e}	46.84(2.54)^{j}	0.95(0.05)
Elipar FreeLight 2	10	50.39(3.48)^{ab}	46.27(3.16)^{h}	0.92(0.06)
	20	53.73(1.72)^{d}	49.61(2.33)^{i}	0.92(0.06)
	40	57.50(2.64)^{g}	53.23(2.49)^{k}	0.93(0.05)
Ultra-Lume 5	10	50.52(2.09)^{ab}	45.31(2.36)^{h}	0.90(0.06)
	20	51.22(2.12)^{cd}	48.79(4.59)^{i}	0.95(0.06)
	40	52.94(2.58)^{f}	50.38(1.73)^{jk}	0.95(0.05)

Values with the same superscript letter were not statistically different at $p=0.05$.

Table 4. Microhardness (mean and standard deviation) of Z250 exposed to five different light sources

Light source	Time used (seconds)	Top surface (VHN)	Bottom surface (VHN)	Hardness ratio (Bottom/Top)
Elipar TriLight	20	72.68(2.34)^{bcd}	68.89(1.78)^{fgh}	0.95(0.04)
L.E.Demetron I	10	69.99(1.78)^{a}	67.54(0.63)^{ef}	0.97(0.03)
	20	71.77(2.05)^{c}	69.78(1.87)^{g}	0.97(0.05)
	40	72.69(3.26)^{d}	70.61(1.07)^{h}	0.97(0.04)
Elipar FreeLight 2	10	70.43(3.03)^{ab}	68.62(1.57)^{f}	0.97(0.03)
	20	71.26(2.30)^{c}	69.13(2.41)^{g}	0.96(0.06)
	40	72.51(2.06)^{d}	69.83(2.36)^{h}	0.94(0.02)
Ultra-Lume 5	10	70.35(0.96)^{ab}	66.13(1.55)^{e}	0.94(0.02)
	20	72.41(1.42)^{c}	69.74(2.18)^{g}	0.96(0.03)
	40	73.29(1.51)d	69.66(2.55)^{h}	0.95(0.04)

Values with the same superscript letter were not statistically different at $p=0.05$.

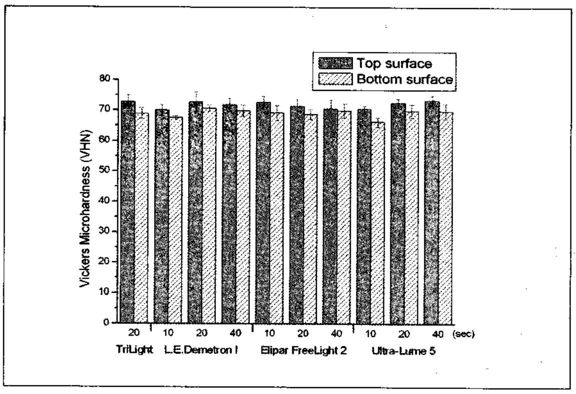

Fig. 2. Vickers hardness of Z250 using different curing lights.

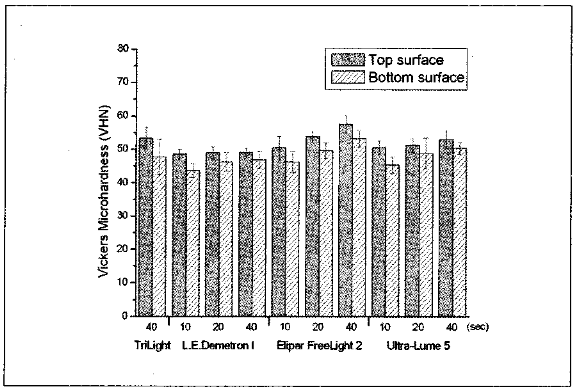

Fig. 3. Vickers hardness of Dyract AP with different curing lights.

Table 5. Microhardness (mean and standard deviation) of Dyract AP exposed to four different light sources

Light source	Time used (seconds)	Top surface (VHN)	Bottom surface (VHN)	Hardness ratio (Bottom/Top)
TriLight	40	$37.08(3.31)^{ace}$	$32.92(1.67)^{hijm}$	0.85(0.07)
L.E.Demetron I	10	$38.81(1.10)^{ab}$	$31.58(1.09)^{hi}$	0.81(0.04)
	20	$39.03(0.77)^{c}$	$34.90(2.12)^{jk}$	0.89(0.06)
	40	$41.23(1.31)^{f}$	$39.99(1.37)^{no}$	0.97(0.04)
Elipar FreeLight 2	10	$38.38(0.75)^{ab}$	$30.92(1.30)^{h}$	0.81(0.04)
	20	$41.28(1.25)^{d}$	$36.15(1.10)^{k}$	0.86(0.04)
	40	$41.97(1.45)^{f}$	$38.80(1.20)^{n}$	0.92(0.04)
Ultra-Lume 5	10	$39.85(1.65)^{b}$	$34.09(3.27)^{i}$	0.86(0.08)
	20	$43.06(2.37)^{d}$	$38.76(1.27)^{l}$	0.90(0.06)
	40	$44.58(3.20)^{g}$	$41.91(2.14)^{o}$	0.94(0.05)

Values with the same superscript letter were not statistically different at $p=0.05$.

Dyract AP

Both FreeLight 2 and UltraLume 5 showed significant higher hardness values than the control (TriLight 40s) at 20- and 40-seconds, whereas there was no significant difference between L.E.Demetron I and the control.

At 10-seconds, UltraLume5 showed significant higher hardness values than the control at top surface, whereas there were no significant differences between the FreeLight 2 and L.E.Demetron I and the control on both surfaces, although they are generally harder than the control.

The hardness ratio of the top/bottom surfaces were as follows : with Dyract AP/TriLight the bottom/top ratio was 85% at 40-seconds; with Dyract AP/FreeLight 2, the bottom/top ratio was 81%, 86%, and 94% at 10-, 20-, and 40-seconds, respectively with Dyract AP/L.E.Demetron I it was 81%, 89%, and 97%; with Dyract AP/Ultra-Lume 5 it was 86%, 90 and 94% (Table 5, Fig. 3).

Ⅳ. Discussion

In recent years, the need for esthetic tooth-colored restorations has led to an increase in the use of resin composites, and these are now an important class of materials commonly used in various restorative procedures. The majority of these materials contain monomers such as 2,2 bis4-(2-hydroxy-3-methacryloyloxypropoxy)-phenyl]propane(Bis-GMA), urethane-ethoxy dimethacrylate(UEDMA), and triethylene glycol dimethacrylate(TEGDMA), as well as usually camphorquinone as a photosensitizer for free-radical polymerization[25,26]. This photosensitizer is sensitive in the blue region of the visible spectrum. The most efficient wavelengths for activation are between 450nm and 490nm, with a maximum of 470nm[27]. For many years now, halogen lamps have been used to cure resin composites. A 400-500nm bandpass filter is used to remove undesired wavelengths from the white halogen source, resulting in the typical blue light of a dental curing unit[28]. As the light intensity rapidly decreases into the depth of a restoration, curing times of up to 40s are often required to cure the composites to an adequate depth. To enhance the curing efficiency, and to allow the dentist to work faster, manufacturers continue to develop light sources with higher intensities. Recently, LEDs have been widely used as an alternative source for curing resins.

The efficiency of a light source can be assessed by curing the resin composite and evaluating its mechanical, physical or chemical properties. One of the mechanical properties that is widely used for this purpose is hardness. The difference between the hardness values of restorative grade materials is dependent on many factors such as shade, amount of filler, type of filler, and the energy and wavelength of the light emitted by the curing light[3]. The curing efficiency can also be assessed by determining the depth of the cure. Depth of cure may be assessed directly or indirectly. Indirect methods for evaluating depth of cure have included scraping, visual, dye uptake and surface hardness methods. Incremental surface hardness measurements have been used in many studies because surface hardness has been shown to be an indicator of the degree of polymerization. The degree of polymerization of a photoinitiated material is dependent on the wavelength and intensity of light output from the curing unit, curing time, the size, location and orientation of the tip of the source, and the shade, thickness and composition of the material[29]. Direct methods which assess degree of conversion, such as an infra-red spectroscopy or a laser Raman spectroscopy, have not been accepted for routine use because the methods are complex, expensive and time consuming. Hardness testing has been the most popular method for investigating factors which influence depth of cure because of the relative simplicity of the method.

In this study, three commercial LED-based curing lights used different numbers of LEDs and different optical configurations. There was no obvious relationship between the number of LEDs and the depth of cure or microhardness. This could be due to the different sizes or wavelengths and power of the LEDs, as well as differences in the efficiency of the optical delivery system, including the light guide tips[30-32].

The main purpose of this study was to evaluate contemporary commercial LED curing lights, and to determine their performance as compared to a conventional halogen curing light. The results showed that an LED source was capable of a significantly greater depth of cure for three different types of composites than a halogen LCU.

In the case of point 4, L.E.Demetron I showed a significantly lower hardness value than the control ($p<0.01$), but there was no statistically significant difference on the bottom surface, for 10-, 20-, and 40-seconds, respectively. On the bottom surfaces, there were no significant differences for 10 and 20 seconds between the FreeLight 2 and the control, whereas they presented higher hardness values for 40-second than the control ($p<0.01$).

Ultra-Lume 5 showed no difference at 10-second and higher mean values compared with the control at 20- and 40-seconds for the bottom surface. These results suggested that FreeLight 2, Ultra-Lume 5, and L.E.Demetron I were able to polymerize point 4 in 20 seconds to a degree equal to that of the halogen control at 40 seconds. The hardness differences found at both the top and bottom surfaces of point 4 among the three LED lights for 20 seconds was in the following order: FreeLight 2 > Ultra-Lume 5 > L.E. Demetron I.

In the case of Z250, L.E.Demetron I and FreeLight 2 showed no statistically significant difference on the bottom surface at 10-seconds, whereas Ultra-Lume 5 showed statistically lower values on the bottom surface at 10-seconds than the control. These results suggested that FreeLight 2 and L.E.Demetron I were able to polymerize Z250 in 10 seconds to a degree equal to that of the halogen control at 20 seconds. The hardness differences found on the top surface of Z250 among the three LED lights for 10s was in the following order: FreeLight 2 〉 Ultra-Lume 5 〉 L.E.Demetron I; and on the bottom: FreeLight 2 〉 L.E.Demetron I 〉 Ultra-Lume 5.

In the case of Dyract AP, Ultra-Lume 5 showed significantly higher hardness values than the control on the top surface, whereas there were no significant differences between the FreeLight 2 and the L.E. Demetron I and the control on both surfaces, although they are generally harder than the control at 10-seconds.

These results suggested that FreeLight 2 and L.E.Demetron I were able to polymerize Dyract AP in 10 seconds to a degree equal to that of the halogen control at 40 seconds.

The hardness differences found on both the top and bottom surfaces of Dyract AP among the three LED lights at 10-second was in the following order: Ultra-Lume 5 〉 L.E.Demetron I 〉 FreeLight 2.

A number of studies indicate that increasing curing time (to a certain limit) gives better physical properties to composite resins. Previous studies have shown that microfilled resin-based composites demonstrate a decreased depth of cure compared with hybrid and macrofilled resin-based composites[10,12,14,33]. It is thought that microfilled resin-based composites are more difficult to cure because their small filler particles cause light to scatter, decreasing the effectiveness of the curing light[14].

The Vickers hardness of the three composites correlates with the filler loading of the composites (Table 1): the greater the filler loading the greater the Vickers hardness. Z250 was the hardest, followed by Point 4 and finally Dyract AP.

Uhl et al[34] reported that the depth of cure data shows that the LED LCU achieved a statistically significantly greater depth of cure than the halogen LCU for all composites and shade. The statistical analysis of the Knoop hardness data, however, showed that the LED LCU did not perform as well for all composites as the depth of cure results suggested. Many light polymerized composites contain only the photoinitiator camphorquinone(absorption maximum 468nm) for the generation of free radicals: thus the free radical polymerization reaction. In addition to camphorquinone, some composites contain other photoinitiators, the so-called coinitiators, which absorb light at shorter wavelengths(〈 410nm). LED LCU does not emit light below 410nm, while the halogen LCU emits down to approximately 330nm. The present studies also confirmed the findings of previous studies[15,16].

Previous studies have used bottom/top Vickers hardness ratios to obtain a percentage depth of cure, and if that value exceeded 80 percent, the specimens were considered to be adequately polymerized[35-37]. Rueggeberg et al[10] found that a 10 percent reduction in intensity resulted in a significant reduction in the hardness. Pilo & Cardash[38] suggested that the top to bottom microhardness ratio should be higher than 0.8 for adequate in-depth polymerization. The microhardness ratio values recorded in the present study exceed the above threshold limit by up to 2mm in depth. There were major differences between the different composite brands, with Z250 displaying the least difference between top and bottom hardness values. The present study supports previous studies that showed there was a better correlation between and the hardness at the bottom than the hardness at the top of the composite[10,39-41].

Hardness values may not be used as absolute indicators of composite cure, only relative ones. They cannot be compared to or among other commercial products, because their resin systems and filler content are not similar. Other types of composites that may be more or less photosensitive may provide different curing patterns with the lights tested. Futhermore, since the compomers have a much lower filler content and are of a different type, they therefore yielded a lower surface hardness. Thus, the reader is cautioned in applying the results of this study universally to all types of composites and curing units. However, within the restrictions imposed by the experimental modes, these comparisons of the potential for resin cure among different types of curing lights and methods are presented.

Ⅴ. Conclusion

To evaluate the effects of different light-curing techniques on the microhardness of three resin composites and to determine their optimal curing time, two types of restorative materials, namely composites Point 4 and Z250, as well as a polyacid modified composite resin, Dyract AP, were selected, and curing was conducted using a conventional halogen unit and three LED curing lights. Vickers hardness numbers (VHN) for the top and the bottom of 2mm thick samples of a dental composite, as well as hardness ratios, were obtained 24 hours after exposure.

1. FreeLight 2, Ultra-Lume 5, and L.E.Demetron I were able to polymerize point 4 in 20 seconds to a degree equal to that of the halogen control at 40 seconds.
2. FreeLight 2 and L.E.Demetron I were able to polymerize Z250 in 10 seconds to a degree equal to that of the halogen control at 20 seconds.
3. FreeLight 2 and L.E.Demetron I were able to polymerize Dyract AP in 10 seconds to a degree equal to that of the halogen control at 40 seconds.
4. All three LED curing units and the halogen curing unit were able to cure the test-composites with bottom/top ratios from approximately 80% to 99%. There were little differences between the different composite brands, with Z250 displaying the least difference between top and bottom hardness values.

The commercially available LED curing lights used in this study showed an adequate microhardness with less than half of the exposure time of a halogen curing unit, thereby demonstrating the potential to replace halogen LCUs.

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Abstract

THE EFFECTS OF VARIOUS CURING LIGHT SOURCES ON THE MICROHARDNESS OF LIGHT-ACTIVATED RESTORATIVE MATERIALS

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The aim of this study is to evaluate the effects of blue light emitting diode (LED) Light Curing Units (FreeLight 2, L.E.Demetron I, Ultra-Lume 5) on the microhardness of three resin composites (Z250, Point 4, Dyract AP) and to determine their optimal curing time. Samples were made using acrylic molds (2.0mm × 3mm) of each composite. All samples were prepared over a Mylar strip placed on a flat glass surface. After composite placement on the molds, the top surface was covered with another Mylar strip and a glass slab was gently pressed over it. The times of irradiation were as follows: Elipar TriLight, 40 s; Elipar FreeLight 2, L.E.Demetron I, and Ultra-Lume 5, 10s, 20s, 40s, respectively. Mean hardness values were calculated at the top and bottom for each group. ANOVA and Sheffe's test were used to evaluate the statistical significance of the results. Results showed that FreeLight 2, Ultra-Lume 5, and L.E.Demetron I were able to polymerize point 4 in 20 seconds to a degree equal to that of the halogen control at 40 seconds. FreeLight 2 and L.E.Demetron I were able to polymerize Z250 in 10 seconds to a degree equal to that of the halogen control at 20 seconds. FreeLight 2 and L.E.Demetron I were able to polymerize Dyract AP in 10 seconds to a degree equal to that of the halogen control at 40 seconds.

The commercially available LED curing lights used in this study showed an adequate microhardness with less than half of the exposure time of a halogen curing unit.

Key words : Composite resin, Halogen curing light, Light emitting diode, Microhardness