Effects of plasma arc curing lights on the surface hardness of the composite resins

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Abstract

In recent years, xenon plasma arc lamp was introduced for high-intensity curing of composite filling materials in direct resin restorations. In this study, two types of restorative materials, namely composites point 4® and Z250® were selected and curing was conducted using a conventional halogen light and two plama curing lights. Two different resin composites were cured using the different units(Flipo®, Ultra-lite 180A, and TriLight®) and tested for microhardness.

The purpose of this study was to test the hypothesis that exposure to a plasma curing lamp for 3, 6, 9 seconds is equivalent to 20 or 40 seconds of irradiation using a conventional halogen curing unit.

1. Flipo® and Ultra-lite 180A were able to polymerize point 4® at 6 seconds to a degree equal to that of the TriLight®(control) at 40 seconds.
2. Flipo® was able to polymerize Z250® at 9 seconds to a degree equal to that of the TriLight®(control) on the bottom surface at 20 seconds, whereas Ultra-lite 180A could not do.
3. Two plasma curing units were able to cure the test-composites with bottom/top ratios approximately 61% to 96% at 3 to 9 seconds. There were some differ-ences between the two composite brands, with Z250® displaying less difference between top and bottom hardness values.

For point 4® and Z250®, at least 6 or 9 seconds were necessary to produce microhardness equivalent to that of the TriLight® curing at 20 or 40 seconds.

Key words : Plasma curing lights, Composite resins, Microhardness

Ⅰ. INTRODUCTION

Today, resin composites are widely used in dentistry for various purposes. Therefore, scientific interest has focussed on polymerization. Photoactivated resin composites are polymerized in the range of 400~520nm. Polymerization of resin composites depends upon the light absorption and dispersion within the resin composite, the shade and opacity of the composite, the filler type and filler load, the concentration of the photoinitiator, the power density delivered by the curing unit, and the irradiation time among other factors[1-3].

The most frequently employed composite resins have camphorquinone(CQ) as a photoinitiator, which is sensitive to light in the blue region of the visible

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spectrum. According to Nomoto, the most efficient wavelength is 470nm, and the best range of wavelength is in the 450~490nm range. Only wavelengths around 470 nm are strongly absorbed by the photosensitizer[4].

For many years, quartz tungsten halogen lights (QTH) have been more widely employed than any other device as a practical alternative method to cure resins. The spectral impurities of conventional curing-lights deliver several wavelengths that are highly absorbed by dental materials, inducing heating of the tooth and resin during the curing process. Another drawback in the use of conventional curing-lights is a decline in irradiance over time due to bulb and filter aging[2]. In addition, the long curing times are inconvenient for the patient, impractical with children, uncomfortable for the dentist, and make the treatment more expensive because of the extra time in the chair.

Various attempts have been made to enhance the speed of the light-curing process, by using a larger light guide or laser devices[5-10].

In recent years, xenon plasma arc lamp was introduced for high-intensity curing of composite filling materials in direct resin restorations. This lamp generally has a tungsten anode and a cathode in a quartz tube filled with xenon gas. When an electric current is passed through xenon, the gas becomes ionized and forms a plasma made up of approximately equal numbers of negatively and positively charged particles. When the xenon gas in the tube is at low pressure, it emits light in a spectrum that resembles daylight[11]. Whereas the conventional halogen lamp emits white light, which is subsequently filtered to produce blue light with a wavelength of 400 to 500nm and an energy level of approximately 300 mW/cm^2, the plasma arc lamp has a much higher peak energy level of 900mW/cm^2 and a narrower spectrum, approximately 430 to 490nm[12].

Due to the high intensity, the manufacturer claims that 3seconds of plasma irradiation cures resin composites to physical properties similar to that achieved after 40seconds with conventional curing units. Such a reduction in irradiation time is attractive to the practitioner, since long curing times are uncomfortable for the patient and might make the treatment more expensive because of extra time in the chair[13].

However, due to the reduction in bottom surface hardness and conversion of conventional resin composites with increasing thickness, it has been recommended that composites should not be irradiated in increments greater than 2.0mm thick[14-17].

Several studies have shown that the high irradiance delivered by the plasma arc lamp over a few seconds is not adequate to bring about optimum properties in resin composites and it also has a marked influence on the degree of polymerization[13, 18-23].

The purpose of this study was to test the hypothesis that exposure to a plasma curing lamp for 3, 6, 9 seconds is equivalent to 20 or 40 seconds of irradiation using a conventional halogen curing unit. Therefore, two different resin composites were cured using the different units and tested for microhardness.

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 composite resins(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 this study, two types of restorative materials, namely composites point 4®(sds/ Kerr, Orange, CA, USA) and Z250®(3M ESPE, St. Paul, MN, USA), were selected, and curing was conducted using a conventional halogen light and two plama curing lights. The restorative materials and the curing units used in this study are listed in Table 1 and 2.

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). The irradiatiation times and light intensity were as follows: Elipar TriLight®(3M ESPE, St. Paul, MN, USA) 40 s, 700 mW/cm^2 ; Flipo® White (Lokki, France) and Ultra-lite 180A Plasma® (Rolence, Taiwan), 3, 6, 9 seconds and 1900mW/cm^2 for point 4® and Z250®, respectively. We used 40 seconds with a halogen light as the control in the case of point 4® and 20 seconds in the case of Z250®.

Ten specimens were made for each combination of

Table 1. Light-activated materials used in this study

Composite	Manufacturer	Filler(by volume)	Filler particle size(μm)
point 4®	sds/ Kerr, Orange, CA, USA	57%	0.4 average
Filtek Z250®	3M Dental Products, St Paul, Mn, USA	60%	0.01-3.5(0.6 average)

Table 2. Light curing units used in this study

Curing light	Type	Curing time(sec)	Light intensity(mW/cm²)
Elipar TriLight	halogen	20, 40	700
Flipo White	plasma	3, 6, 9	1900
Ultra-lite 180A Plasma	plasma	3, 6, 9	1900

light source and composite: a total of 150 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 10seconds. 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 groups. 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 different light curing units(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 were obtained 24 hours after curing using a halogen curing unit and the two plasma curing units. Data for microhardness, expressed as VHN for the top/bottom surfaces, and the hardness ratio are shown in Tables 3 to 5. Fig. 1 to 3 shows the mean VHN of the top and bottom surfaces according to the various curing lights and composite resins.

point 4®

Flipo® showed lower hardness values on both the top and bottom surface at 3 second ($p<0.05$), whereas there were no differences at 6 second and inversely hardness value of 9 second top surfaces with Flipo® was higher than the control($p<0.05$).

Ultra-lite 180A also showed lower hardness values than the control in both the top and bottom surfaces at 3 second($p<0.05$), whereas it showed higher hardness values but there was no significant difference between the two units at 6 and 9 second, with the exception of 6 second bottom surface, which yielded lower values.

The hardness ratio of the top/bottom surfaces were as follows: with TriLight® the bottom/top ratio was 89% at 40 seconds; with Flipo®, the bottom/top ratio was 65%, 91%, and 86%, at 3, 6, 9 seconds, respectively; with Ultra-lite 180A, it was 61%, 81%, and 88% (Table 3, Fig. 1).

Z250

Flipo® showed lower harness values in both the top and bottom surface at 3-second and bottom surface at 6 second than the control(H_2O)($p<0.05$), whereas there was no difference in hardness value on the top of 6 second and both surfaces of 9 second.

Ultra-lite 180A also showed lower hardness values than the control(H_2O) in both the top and bottom surfaces at 3, 6, 9 second($p<0.05$), with the exception of 9 second top surface, which yielded lower hardness values but there was no significant difference.

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®/Flipo®, the bottom/top ratio was 85%, 92% and 96%, at 3, 6, 9 seconds, respectively; with Z250®/Ultra-lite 180A it was 83%, 91% and 94%(Table 4, Fig. 2).

Table 3. Microhardness(mean and standard deviation) of point 4® after curing with three different light sources

Light source	Time used (second)	Top surface hardness(VHN)*	Bottom surface hardness(VHN)*	Hardness ratio (Bottom/Top)
TriLight	40	53.37(3.17)^{cde}	47.71(5.29)^{hij}	0.89(0.06)
Flipo White	3	40.31(1.44)^{a}	26.19(2.60)^{g}	0.65(0.06)
	6	52.62(2.47)^{d}	47.77(2.83)^{i}	0.91(0.06)
	9	57.07(2.49)^{f}	48.91(3.82)^{j}	0.86(0.07)
Ultra-lite 180A	3	47.48(3.86)^{b}	28.55(2.16)^{g}	0.61(0.08)
	6	54.83(2.83)^{d}	44.59(2.39)^{i}	0.81(0.06)
	9	55.57(3.18)^{ef}	49.05(3.34)^{j}	0.88(0.07)

* : $p<0.05$, by one way ANOVA
$^{a-j}$: values with same superscript letter were not statistically different by Duncan's post hoc test at $p=0.05$

Table 4. Microhardness(mean and standard deviation) of Z250® after curing with three different light sources

Light source	Time used (second)	Top surface hardness(VHN)*	Bottom surface hardness(VHN)*	Hardness ratio (Bottom/Top)
TriLight	20	72.68(2.34)^{cef}	68.89(1.78)^{iln}	0.95(0.04)
Flipo White	3	68.51(1.43)^{b}	58.49(1.34)^{h}	0.85(0.03)
	6	71.63(2.23)^{de}	66.10(1.24)^{k}	0.92(0.04)
	9	71.98(2.82)^{f}	68.92(0.74)^{n}	0.96(0.04)
Ultra-lite 180A	3	65.91(1.82)^{a}	54.65(2.31)^{g}	0.83(0.03)
	6	69.43(2.50)^{d}	62.92(1.21)^{j}	0.91(0.04)
	9	70.44(1.34)^{f}	66.35(1.84)^{m}	0.94(0.03)

* : $p<0.05$, by one way ANOVA
$^{a-j}$: values with same superscript letter were not statistically different by Duncan's post hoc test at $p=0.05$

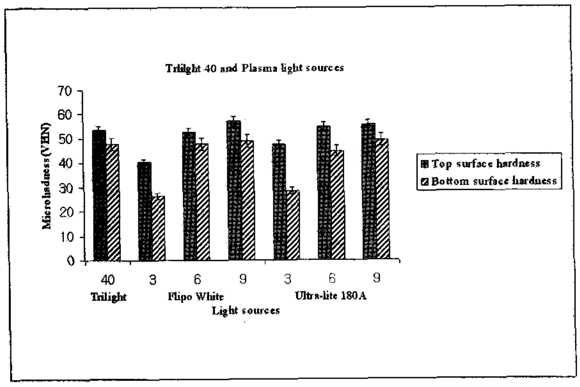

Fig. 1. Vickers hardness of point 4® using different curing lights.

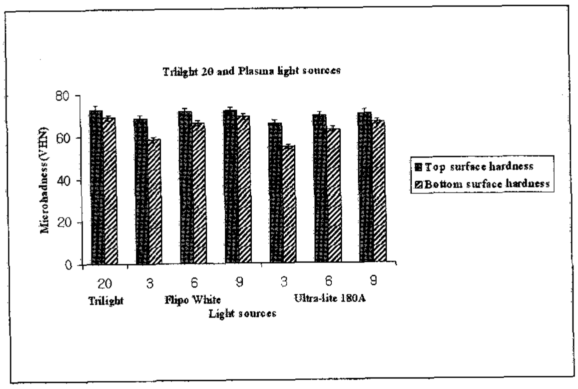

Fig. 2. Vickers hardness of Z250® using different curing lights.

Ⅳ. DISCUSSION

Plasma arc lights are increasingly used by dentists because they supposedly allow for a reduction of curing time, due to their elevated light output, which is considered a significant advantage over conventional halogen light curing units[13]. Obviously, the efficiency of plasma arc curing units strongly depends on which photoinitiators the resin composites contain; thus, the manufacturers of resin composites should provide information on the type of photoinitiator used or on the required spectral radiometric output necessary for photoactivating their material. Based on these information, the dentist can decide for himself whether plasma curing is appropriate or not for a given resin composite[21)].

The main purpose of this study was to evaluate the curing effectiveness of contemporary commercial plasma curing lights, and to determine their performance as compared to a conventional halogen curing light. In order to test the hypothesis that exposure of resin composites to two plasma curing lamps for 3, 6 or 9seconds is equivalent to 20 or 40 seconds of irradiation using a conventional halogen curing unit, microhardness exhibited by two different composite resins with these three curing units were compared. All composite resins used contain camphorquinone as a photoinitiator.

A strong correlation has been reported between microhardness and the degree of cure within one type of dental composite[24-26)]. The measurement of the hardness of the surface exposed to the source of light when compared to the hardness of the surface below gives an indication of the degree of cure through the thickness of the material. 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[27)].

In general, the microhybrid resin-based composite had the greatest depth of cure, whereas the flowable resin-based composite had the least depth of cure[28)]. The composition of a resin-based composite has been shown to affect the depth of cure. The resin-based composites with smaller filler particles are more difficult to cure than are the resin-based composites with larger filler particles. Smaller filler particles(0.01 to 1 micron) are most likely to scatter light because those particle sizes are similar to the wavelengths emitted from composite curing lights, which makes it harder for light to penetrate deep into the material and means that greater irradiance or longer exposure times are needed to cure small particle resin-based composites. All of the microfills and many of the hybrid composites used today have filler particles that fall into that size range. Therefore, we would expect less depth of cure when these types of composites are used. However, the relative contribution of filler size to the other factors, such as duration of exposure and thickness of an overlying material, is very small. Krishnan and Yamuna suggested that a particle size of 0.7~1㎛ was found to produce better properties[29)]. The ratio of filler to unfilled resin matrix also important. The higher the proportion of filler particles, the more difficult it is for light to pass through the resin-based composite[29-31)].

As the stipulated minimum requirement of Vickers microhardness is 34kg/mm^2 for dental composites (Reports of Council & Bureaus, 1977) it can be deduced that a minimum concentration of 0.25% CQ at an exposure time of 30seconds each on both sides is required for satisfactory performance of the composite in the oral cavity[29)].

Regarding the resin post-irradiation polymerization, Johnston et al, Yearn, and Pilo and Cardash reported that microhardness increased rapidly over the first hour, increased slowly during 24hrs and showed no further increase after 24 hrs[3,14,32)].

This study has shown that polymerization characteristics produced by two such units, although in several instances different from a statistical point of view, may be evaluated as being fairly close from a practical point of view to the characteristics associated with a conventional curing unit. It is questionable whether the very short cure time per layer is reflected in a shorter time for the entire restorative procedure.

The results of the present study show that irradiating point 4® and Z250® for 3 seconds using the Ultra-Lite 180 A plasma and Flipo® produces a significantly softer composites than when irradiated using a QTH light for 40 seconds. It can be concluded that the plasma arc curing unit, Ultra-Lite 180 A plasma and Flipo®, did not provide optimal cure when used as recommended by the manufacturer. This is in agreement with several earlier publications[13,18-22,33-35)].

For the Flipo® light, the results indicate that a minimum 6 second exposure in point 4®, 9 second in Z250® should be used to provide composite hardness at 2 mm depth similar to that achieved with the control.

For the Ultra-Lite 180 A, the results indicate that a minimum 6 second exposure in point 4® was needed, but in Z250® they suggested that a little more time should be needed to provide composite hardness at 2 mm depth similar to that achieved with the control.

A comparison between TriLight® and Flipo® in Z250® shows that Flipo® at 9seconds result in greater hardness value than does TriLight® at 20, 40 seconds, respectively. This difference explains that the relative effectiveness of curing units depends on the composite resins. This is in agreement with several earlier publication[27,36]. The reason for this has only been touched upon in the literature[27]. Assuming that all materials employ camphorquinone as photoinitiator, the difference may be associated with the use of different amines, forming complexes with camphorquinone of different absorption characteristics. The amines used in the investigated resin composites were not identified, but may well be of different chemical composition. Anecdotal evidence will have it that certain resin composites and certain dentin-bonding agents do not polymerize well with PAC light. This may indicate that the rather narrow band of wavelengths emitted by PAC curing units is outside the range of maximum sensitivity of the camphorquinone/amine complex of these materials.

Previous studies have shown that microfilled resin-based composites demonstrate a decreased depth of cure compared with hybrid and macrofilled resin-based composites [37,38,39]. 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[39].

As expected, Z250® produced higher values of VHN than point 4® for all curing methods. The hardness of Z250® cured by the halogen and plasma curing produced higher than that of point 4®

Although 6 seconds irradiation with the plasma arc unit seems to be sufficient for curing point 4® to a degree not significantly different from that obtained with the halogen unit(Fig. 2), this may not be true for all commercial resin composites. Especially not for those using photoinitiators having absorption maximums lower than that of camphorquinone (468nm) because of the rather narrow wavelength around this value emitted from the plasma arc unit.

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[3,32]. Rueggeberg et al found that a 10 percent reduction in intensity resulted in a significant reduction in the hardness[40]. Pilo & Cardash suggested that the top to bottom microhardness ratio should be higher than 0.8 for adequate in-depth polymerization[3]. The microhardness ratio values recorded in the present study exceed the above threshold limit by up to 2mm in depth. Z250® displayed less difference between top and bottom hardness values than that of point 4®. 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[14,40-44].

The increased power density generated by the PAC lights were able to significantly reduce the exposure duration for direct polymerization of 2 mm thick composite samples in comparison with QTH light. This reduction can lead to a significantly reduced chair time, especially when incremental techniques are applied. However, using indirect polymerization, a distinct prolongation of exposure duration was required for the PAC light. Undifferentiated recommendation of exposure durations for the PAC lamp is therefore not appropriate. Rather, meticulous guidelines with respect to exposure must be established for each single clinical indication and specific brand to ensure properly cured restorations.

The results showed that exposure from the Flipo® and Ultra-Lite 180 A should be at least 6 or 9 seconds to provide hardness values at 2 mm depth similar to those seen with the standard QTH method. However, a 3 seconds curing time with the Flipo® and Ultra-Lite 180 A as recommended by the manufacturer was not sufficient to provide adequate microhardness of the different resin composites tested.

Ⅴ. CONCLUSION

To evaluate the effects of different light-curing lights 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® were selected and curing was conducted using a conventional halogen unit and two plasma curing lights. Vickers hardness numbers (VHN) for the top and the bottom of 2 mm thick samples of composite resins, as well as hardness ratios, were obtained 24 hours after exposure.

1. Flipo® and Ultra-lite 180A were able to polymerize

point 4® at 6 seconds to adegree equal to that of TriLight® at 40 seconds.

2. Flipo® was able to polymerize Z250® at 9 seconds to a degree equal to that of the TriLight®(control) on the bottom surface at 20 seconds, whereas Ultra-lite 180A couldn't do.
3. Two plasma curing units were able to cure the test-composites with bottom/top ratios approximately 61% to 96% at 3 to 9 seconds. There were some differences between the different composite brands, with Z250® displaying the least difference between top and bottom hardness values.

For point 4® and Z250®, at least 6 or 9 seconds were necessary to produce microhardness equivalent to that of TriLight® curing at 20 or 40 seconds.

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국문초록

플라즈마 광중합기가 복합레진 중합에 미치는 영향

이수원 · 최남기 · 양규호 · 김선미

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기존에 사용하고 있는 할로겐 광중합기는 여러 가지 장점에도 불구하고 중합시간이 오래 걸린다는 문제 때문에 시술시간이 길어지는 단점이 있는데, 최근에 개발된 플라즈마 광중합기는 매우 짧은 시간에 중합시킬 수 있다고 제조회사는 주장하고 있다. 본 연구에서는 임상에서 흔히 상용하고 있는 복합 레진을 광중합 할 때, 할로겐 광중합으로 얻을 수 있는 플라즈마 광중합기의 적절한 중합시간을 알아보고자 한다. 2mm 두께의 레진 샘플을 만들어 광중합 하고 24 시간 후 상,하면의 미세경도를 측정하였다.

point 4®에서는 플라즈마 광중합기로 6초간 중합했을 때 할로겐과 유사한 경도를 얻었지만, Z250®에서는 Flipo®만 9초간 중합시 할로겐과 유사한 광중합을 나타냈다.

이번 연구에서 사용한 플라즈마 광중합기는 적어도 6초 혹은 9초정도 광중합 했을 때 할로겐과 유사한 중합을 얻을 수 있다는 것을 알 수 있었다.

주요어 : 플라즈마 광중합기, 복합레진, 미세경도