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The Influence of Plastic Light Cure Sheaths on the Hardness of Resin Composite

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Clinical Relevance

Disposable sheaths are now recommended as a method of cross infection control when light curing resin composite. However, these sheaths may affect the depth of cure of the resin composite, resulting in a compromise of the mechanical properties of the restorative material.

SUMMARY

Objective: This study investigated the influence of a disposable light cure sheath on both the surface hardness and hardness at varying thicknesses of resin composite.

Methods: A series of resin composite discs (Spectrum) were fabricated with varying depths up to 6 mm. The light curing units used were a standard halogen unit (Elipar Trilight) and an LED unit (Elipar Freelight 2). Recommended curing times from the manufacturer were followed. The disposable light-curing sheath (Cure Sleeve) was used with both light-curing units. Two additional groups without the sheath were employed as controls. Each specimen (n=4) was subjected to hardness testing to evaluate hardness from 0 mm to 5 mm thick. A 200g load was applied for 10 seconds using a Vickers diamond indenter and six indentations were obtained from each specimen. Statistical analysis was performed using two-way ANOVA.

Results: The LED without a sheath achieved the highest surface hardness value (47.2 VHN ± 5.5). There was no significant difference between the groups regarding surface hardness (p>0.05). As the thicknesses of the resin composite increased, the hardness values decreased in all groups. The LED light curing unit, in combination with a sheath, demonstrated the lowest hardness values at a 5 mm thickness of resin composite (p<0.05).

Conclusion: All four different methods of light curing resulted in a significant reduction in hardness values with increasing resin composite thickness, which could compromise the mechan-

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ical properties of the resin composite. However, the use of the light cure sheaths still provided an acceptable depth of cure when used following the 2 mm increment rule. It was not until 3 mm that the use of the light cure sheaths compromised the hardness results. It is recommended that the curing depth should not exceed 2 mm, regardless of light curing method.

INTRODUCTION

High levels of cross infection control are needed to protect patients and staff when using light curing units due to contact with the oral environment. Caughman and others[1] found that the contamination of light curing units and handles was common after clinical use. Several methods of infection control are available for the tips of light curing units. These methods include disinfectant wipes, autoclavable guides, pre-sterilized single-use plastic sheaths and transparent disposable barriers to cover the light-curing tip. Disposable sheaths provide a cost effective way to avoid contamination of the light-curing tip. They are convenient, non-invasive and prevent contact between the oral tissues and the tip. They also eliminate the risk of damaging the light cure tip by autoclaving or disinfection.

However, a number of studies have reported that the use of disposable sheaths significantly reduces the intensity of the light.[2-3] Optimal polymerization is essential for a successful light-cured restoration. Inadequate curing of the resin composite will lead to premature breakdown at the tooth-restoration interface, staining of the restoration, dimensional instability, decreased biocompatibility of the resin and increased cytotoxicity.[4-6] Warren and others[7] investigated different types of barriers and found that all methods reduced light output. If the amount of light reaching the resin composite is reduced, then the depth of cure and surface hardness may be decreased. Studies have also shown that light intensity reduces as the distance from the resin composite increases for both halogen and LED light curing units, but it is not clear whether such declines in light intensity significantly affect the depth of cure of the material.[8]

The current study investigated the influence of a disposable transparent plastic light cure sheath on both the surface hardness of resin composite and the hardness at varying thicknesses of resin composite. The null hypothesis to be tested is that there is no significant difference between resin composites cured with either halogen or LED light curing units when used alone or in conjunction with a disposable plastic light cure sheath.

METHODS AND MATERIALS

The resin composite used in the current study was the submicron hybrid composite restorative material Spectrum (Dentsply, DeTrey, Konstanz, Germany, shade B1 and batch #0207001847). The halogen light-curing unit used was Elipar Trilight (3M ESPE, Seefeld, Germany), which has a wavelength range of 400-515 nm and an irradiance of 800mW/cm^2. Curing was performed for 40 seconds as recommended by the manufacturer. The LED light curing unit used was Elipar Freelight 2 Cordless LED Curing Light, 3M ESPE, Seefeld, Germany, with a wavelength range of 440-490 nm and an irradiance of approximately 400mW/cm^2. With this light curing unit, curing was carried out for 20 seconds, as per the manufacturer's instructions. This unit has a built-in test area on the charger, enabling the light intensity output to be checked. Before each cure with this light, the light intensity output was checked to ensure maximum output. The light cure sheaths were single-patient use (Cure Sleeve Model 4500, Pinnacle, Kerr, Orange, CA, USA).

The molds were constructed from clear perspex of varying thicknesses with graduations of up to 6 mm to allow a series of resin composite discs to be produced. A Mylar strip (Hawe-Neos Dental, Bioggio, Switzerland) was placed underneath the mold to prevent adherence of the resin composite to the under surface and to prevent the formation of an oxygen-inhibited layer. Individual compules of resin composite were used, with a fresh compule being used for each sample. The resin composite was placed in the mold using a composite gun, and the surface of the material was smoothed using a flat plastic instrument and covered with a Mylar strip, therefore, preventing any resin composite from coming into direct contact with the light curing tip. The samples were then cured for the required length of time, ensuring that the tip of the light-curing unit was directly flush with the upper surface of the sample. An orange light cure shield was used during curing for protection from the blue light. The Mylar strips were removed and the mold was then mounted onto the platform of the LECO M-400 hardness tester (LECO, St Joseph, MI, USA). Each specimen (n=4) was tested on the top and bottom surfaces under a 200g load applied for a 10 second dwell time using a Vickers diamond indenter. Six values were recorded on each side of each sample and averaged for statistical analysis. The procedure was performed on four groups: the halogen light cure unit only, the halogen light cure unit plus sheath, the LED light cure unit only and the LED light cure unit plus sheath. When using the sheath, it was ensured that no air was trapped within the sheath and that the sheath was pulled tightly over the light cure tip. A fresh sheath was used for each sample.

Statistical analysis was undertaken using two-way ANOVA with Tukey's post-hoc tests (SPSS for Windows, version 14.0, SPSS Inc, Chicago, IL, USA) to determine if there were any significant differences in surface hardness and hardness at different thicknesses between the resin composites cured by either halogen or LED light curing units when used with or without a sheath. The results were considered significant for $p<0.05$.

RESULTS

The surface hardness results were obtained from the upper surface of the samples, as this is effectively at a 0 mm depth of the resin composite. The results are shown in Table 1. The highest surface hardness value of 47.2 VHN ± 5.5 was obtained with the LED light-curing unit used without a sheath. The results achieved with the sheaths for both types of light curing units were lower than the samples cured without a sheath. The lowest value of 45.9 VHN ± 5.1 was obtained with the LED light-curing unit plus sheath. However, there was no significant difference between the surface hardness of the resin composite and the four different methods of light curing ($p\geq0.05$).

The hardness values at varying thicknesses were obtained from testing the lower surface of the resin composite discs, as this series of results reflect the depth of cure of the material. The data is presented in Table 1 and is illustrated in Figure 1. From 0 mm to 2 mm, there was no significant difference in hardness values in any of the four groups ($p>0.05$). As the thickness of the resin composite progressed from 2 mm to 3 mm, there were significant differences in hardness values for the halogen light curing unit plus sheath and the LED light-curing unit without a sheath. From 3 mm to 4 mm, no significant difference in hardness values was found in any of the four groups. However, from 4 mm to 5 mm, significant differences in hardness values were found with the halogen light curing unit plus sheath and both LED light curing unit groups but not with the halogen light-curing unit without a sheath. As the thickness of the resin composite progressed from 2 mm to 5 mm, the hardness values decreased in all four groups, most prominently with the LED light-curing unit with a sheath.

Comparing the four groups, at a depth profile of 0 mm, there was no significant difference in hardness values between the groups ($p>0.05$). Similarly at 2 mm, 3 mm and 4 mm, no significant difference among the different light-curing methods was observed. However, at 5 mm, the halogen light-curing unit without sheath showed significantly higher hardness values than the three other groups ($p<0.05$). There was no significant difference between the halogen light-curing unit plus sheath and the LED light-curing unit without a sheath light. The lowest hardness value of 21.3VHN ± 1.6 was recorded at 5 mm, with the LED light-curing unit in conjunction with a sheath, which was significantly lower than the other three groups.

DISCUSSION

In measuring the efficacy of the cure, hardness is used both in evaluating surface hardness of the resin composite and depth of cure.[9] In the current study, the efficacy of curing was evaluated by these two parameters. Hardness is a relative measure of resistance to indentation or abrasion and has been shown to be an indirect measure of the degree of conversion.[10-11] In addition, light intensity can modify the final properties of the material, which could compromise the clinical situation and may be affected by the light curing sheaths. Higher degrees of curing have been shown to improve the final properties of the resin composite.[12]

Evaluation of the depth of cure of the resin composite can be accomplished by direct methods, such as

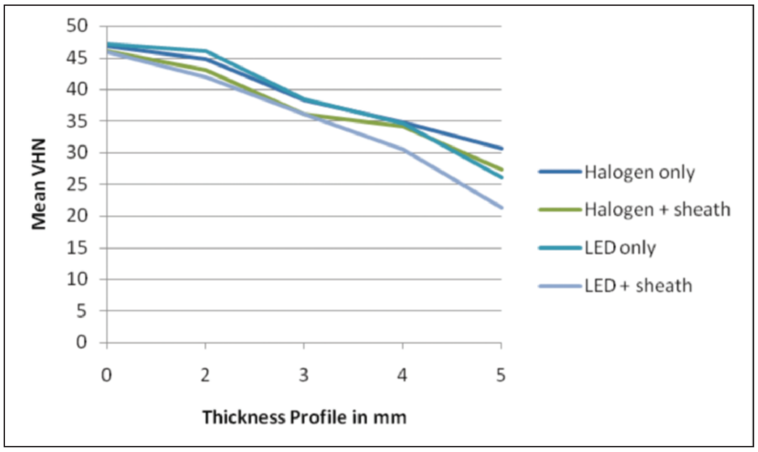

Figure 1. *Mean Vickers Hardness Number and thickness profile of the resin composite cured with halogen and LED light-curing unit with and without the sheath.*

Table 1: *Mean Vickers Hardness Numbers (VHN) and Standard Deviation for the Depth of Cure of the Four Test Groups*

Depth Profile (mm)	Halogen Only	Halogen & Sheath	LED Only	LED & Sheath
0	46.9 (8.5)[a]	46.1 (4.5)[a]	47.2 (5.5)[a]	45.9 (5.1)[a]
2	44.9 (5.9)[a,b]	43.1 (3.1)[a,b]	46.1 (3.7)[a]	42.0 (2.1)[a,b,c]
3	38.4 (4.9)[b,c,d]	36.2 (3.2)[c,d,e]	38.4 (2.3)[b,c,d]	36.1 (2.4)[c,d,e]
4	34.8 (2.6)[d,e]	34.2 (2.7)[d,e]	34.6 (2.9)[d,e]	30.5 (1.7)[e,f]
5	30.7 (5.1)[e,f]	27.3 (1.2)[f,g]	26.1 (2.3)[f,g]	21.3 (1.6)[h]

Groups having the same superscript letter were not statistically different (p>0.05). Groups with different superscript letters indicate significant differences (p<0.05).

infrared spectroscopy and electron resonance, and indirect methods, using Knoop and Vickers hardness testing, both which are popular due to the ease of technique and reliability of the results.[2,6] The Knoop hardness test is popular because the test minimizes the effect of plastic recovery that occurs with resin composites more than with the Vickers hardness test. However, Poskus and others[13] found that there was no significant difference between both the Knoop and the Vickers values. In addition, the Vickers hardness test is often favored, as this test is considered a better indicator of the degree of polymerization of the resin composite.[14-15]

The results of the current study showed no significant difference in the surface hardness of resin composite when cured using the halogen or LED light curing unit both with and without the sheath. Previous studies, however, have reported that the surface hardness values were lower for an LED than the halogen light-curing unit and attributed this to the comparatively lower degree of conversion facilitated by the LED photo polymerization.[16-19] These studies, however, did not involve any type of barrier method. It may be that the conversion process is compromised further by the disposable sheath and, hence, the reason for the slightly lower surface hardness values for the LED unit and sheath in the current study. However, when the LED was used without a sheath, the highest surface hardness results were obtained but were not significantly different from the other light curing groups. If the wavelength of light from the light curing unit is significantly affected when a barrier is used, the resin composite may not be completely cured.[20] Studies have shown that light intensity may fall by up to 35% when some barriers are used.[20] In addition, Rueggeberg and others[2] demonstrated that light intensity may be significantly reduced if the sides of the sheath come into contact with the oral tissues. Scott and others[20] found that the power density from the light curing units was reduced when using two types of barrier methods but plastic wrap had no significant effect on power density. Another study by Chong and others[21] reported significant differences in light intensity output when different barrier methods were used. Although there was no significant difference in surface hardness between the different barrier methods used, a plastic glove and cellophane wrap were considered to be the best methods, as they allowed for the highest light intensity output.

Interesting results were obtained regarding the hardness values, as the thickness of the resin composite increased. There was no significant difference in hardness values in the four different light-curing methods as the thickness progressed from 0 mm to 2 mm. However, from 2 mm to 3 mm, there were statistically significant decreases in hardness values for the halogen light-curing unit plus sheath and the LED light-curing unit without a sheath. The standard incremental placement of composite is 2 mm, therefore, it is imperative that this is adhered to, because, if the increment placed was just slightly more than 2 mm, it could lead to incomplete curing of the resin composite and thus poorer mechanical performance, which could affect the longevity of the restoration. As the resin composite thickness progressed from 3 mm to 4 mm, no significant difference in hardness values was found in any of the four groups. But again, from 4 mm to 5 mm, significant differences in hardness values were found with the halogen light-curing unit plus sheath and both LED light curing unit groups.

As the thickness of the specimen progressed from 2 mm through to 5 mm, there was a significant reduction in hardness values obtained in all four groups, in particular, with the LED light-curing unit plus sheath. At 5 mm, this method of curing demonstrated significantly lower values in comparison with the other groups. Nomoto[22] reported LED maximum irradiation at 466 nm, which is the most efficient wavelength to excite camphoroquinone. However, the light is absorbed and/or scattered when the depth of cure increases, decreasing the amount of energy for photoactivation and therefore lower hardness values are attained. As a result, it is possible that the sheath may further compromise this polymerization process and explain the low results obtained for the LED light-curing unit used in combination with the sheath. It may also be that use of the sheath reduces the intensity of the light emitted by this type of light curing unit and, therefore, has a detrimental effect on the subsequent cure of the material.

The curing time used with the LED light-curing unit was only 20 seconds, as recommended by its manufacturer, and this reduction in curing time may also be a contributing factor. An increased curing time may be preferable when an LED light-curing unit is used with a sheath. At 5 mm, the halogen light-curing unit without the use of a sheath showed significantly higher hardness values compared to the other groups. This is in good agreement with other studies. Jandt and others[17] reported that the mean depth of cure values obtained with a halogen light-curing unit were approximately 20% higher than those obtained with an LED light-curing unit. They attributed the larger depth of cure to the greater irradiance produced by the halogen light-curing unit compared to the LED light-curing unit (800 vs 400 mW/cm^2) and this may also be a factor in the current study.

The results of this study are likely to be exacerbated in true clinical conditions due to the incorrect use of the sheaths and light-curing tips. Often, the sheaths are not placed over the tip correctly and air can become trapped in-between, leading to the light-curing tip being a greater distance away from the restoration and, as a result, the curing effectiveness being reduced. Some clinicians may hold the tip of the light-curing unit slightly further away from the restorative material to ensure that there is no contact between the sheath and the resin composite. It is imperative that the light-cure tip is held in close proximity to the resin composite to achieve optimum depth of cure. Aravamudhan and others[8] found that the intensity and depth of cure decreased with increasing distances away from the resin composite. While the depth of cure usually decreases with decreasing intensity, the rate of decline varied between various light curing unit brands. Further work investigating the curing time and effect of the different brands of disposable sheath and light curing units on surface hardness and resin composite thickness are indicated.

CONCLUSIONS

The current study found that there were no significant differences between the depth of cure of resin composite cured at 0-2 mm using any of the four different light curing methods. In all groups, as the thickness progressed from 3 mm to 5 mm, there was a significant reduction in hardness values. Regarding surface hardness, no significant difference was observed with or without the use of the sheath for both light-curing units. The use of the light cure sheaths provided an acceptable depth of cure when used following the 2 mm increment rule. It was not until 3 mm that the use of the light cure sheaths compromised the performance of the resin composite. Therefore, it is recommended that the thickness of the resin composite must not exceed 2 mm. At greater depths of cure, significant reductions in hardness occurred, with poorer performance relating to the light cure sheath.

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References

1. Caughman GB, Caughman WF, Napier N & Schuster GS (1989) Disinfection of visible-light-curing devices *Operative Dentistry* **14(1)** 2-7.

2. Rueggeberg FA & Caughman WF (1998) Factors affecting light transmission of single-use, plastic light-curing tips *Operative Dentistry* **23(4)** 179-184.

3. Hodson NA, Dunne SM & Pankhurst CL (2005) The effect of infection-control barriers on the light intensity of light-cure units and depth of cure of composite *Primary Dental Care* **12(2)** 61-67.

4. Chen RS, Liuiw CC, Tseng WY, Hong CY, Hsieh CC & Jeng JH (2001) The effect of curing light intensity on the cytotoxicity of a dentin-bonding agent *Operative Dentistry* **26(5)** 505-510.

5. Caughman WF, Caughman GB, Shiflett RA, Rueggeberg F & Schuster GS (1991) Correlation of cytotoxicity, filler loading and curing time of dental composites *Biomaterials* **12(8)** 737-740.

6. Ferracane JL (1985) Correlation between hardness and degree of conversion during the setting reaction of unfilled dental restorative resins *Dental Materials* **1(1)** 11-14.

7. Warren DP, Rice HC & Powers JM (2000) Intensity of curing lights affected by barriers *Journal of Dental Hygiene* **74(1)** 20-23.

8. Aravamudhan K, Rakowski D & Fan PL (2006) Variation of depth of cure and intensity with distance using LED curing lights *Dental Materials* **22(11)** 988-994.

9. Baharav H, Abraham D, Cardash HS & Helft M (1988) Effect of exposure time on the depth of polymerization of a visible light-cured composite resin *Journal of Oral Rehabilitation* **15(2)** 167-172.

10. Asmussen E (1982) Restorative resins: Hardness and strength vs quantity of remaining double bonds *Scandinavian Journal of Dental Research* **90(6)** 484-489.

11. Santos GB, Medeiros IS, Fellows CE, Muench A & Braga RR (2007) Composite depth of cure obtained with QTH and LED units assessed by microhardness and micro-Raman spectroscopy *Operative Dentistry* **32(1)** 79-83.

12. Obici AC, Sinhoreti MA, Correr Sobrinho L, Goes MF & Consani S (2004) Evaluation of depth of cure and Knoop hardness in a dental composite photo-activated using different methods *Brazilian Dental Journal* **15(3)** 199-203.

13. Poskus LT, Placido E & Capel Cardoso PE (2004) Influence of placement on Vickers and Knoop hardness of Class II composite resin restorations *Dental Materials* **20** (8) 726-732.

14. Unterbrink GL & Muessner R (1995) Influence of light intensity on two restorative systems *Journal of Dentistry* **23(3)** 183-189.

15. Peutzfeldt A (1994) Correlation between recordings obtained with a light-intensity tester and degree of conversion of a light-curing resin *Scandinavian Journal of Dental Research* **102(1)** 73-75.

16. Rahiotis C, Kakaboura A, Loukidis M & Vougiouklakis G (2004) Curing efficiency of various types of light-curing units *European Journal of Oral Science* **112(1)** 89-94.

17. Jandt KD, Mills RW, Blackwell GB & Ashworth SH (2000) Depth of cure and compressive strength of dental composites cured with blue light emitting diodes (LEDs) *Dental Materials* **16(1)** 41-47.

18. Kurachi C, Tuboy AM, Magalhaes DV & Bagnato VS (2001) Hardness evaluation of a dental composite polymerized with experimental LED-based devices *Dental Materials* **17(4)** 309-315.

19. Besnault C, Pradelle-Plasse N, Picard B & Colon P (2003) Effect of a LED versus halogen light cure polymerization on the curing characteristics of three composite resins *American Journal of Dentistry* **16(5)** 323-328.

20. Scott BA, Felix CA & Price RB (2004) Effect of disposable infection control barriers on light output from dental curing lights *Journal of the Canadian Dental Association* **70(2)** 105-110.

21. Chong SL, Lam YK, Lee FKL, Ramalingam L, Yeo ACP & Lim CC (1998) Effect of various infection-control methods for light-cure units on the cure of composite resins *Operative Dentistry* **23(3)** 150-154.

22. Nomoto R (1997) Effect of light wavelength on polymerization of light-cured resins *Dental Materials Journal* **16(1)** 60-73.