the Journal of CONTEMPORARY DENTAL PRACTICE at www.thejcdp.com
Volume 8 Number 7 November 1, 2007

Temperature Rise Produced by Different Light-curing Units through Dentin

A. Rüya Yazici, DDS, PhD; Ali Müftü, DMD, MS;
Gerard Kugel, DMD, MS, PhD

Abstract

Aim: This study investigated the temperature rise caused by different light curing units and the temperature increase in dentin of different thicknesses.

Methods and Materials: Dentin discs of 1.0 and 2.0 mm thicknesses were prepared from extracted human mandibular molars. Temperatures were recorded directly at the surface of the light guide tip, under dentin discs with different thicknesses, and through a sandwich composed of 2 mm thick cured composite and dentin using a K-type thermocouple. The curing units used were two quartz-tungsten-halogen lights (Spectrum and Elipar Trilight-ET) and a light-emitting diode (LED).

Results: The highest temperature rise was observed under a Mylar strip using ET standard mode. Under 1 and 2 mm thick dentin barriers, the lowest temperature rise was measured for the LED curing light. Significant differences in temperature rise existed among all curing units except between the Spectrum and ET exponential modes under a 1 mm thick dentin barrier with cured composite. Temperature rises were insignificant between the Spectrum and ET exponential modes and between two modes of Trilight when the same experimental setup was used under a 2 mm thick dentin barrier.

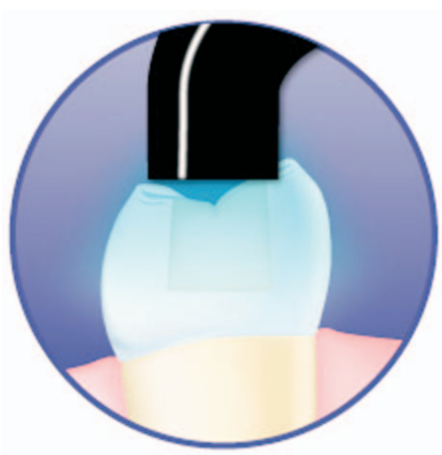
Conclusion: For all curing units, temperature elevation through 2 mm of dentin was less than for 1 mm of dentin thickness. The ET standard mode produced the highest and the LED produced the lowest temperature rise for all tested conditions. The thickness of dentin and light-curing unit might affect temperature transmission.

Keywords: Composite resin, quartz-tungsten-halogen light curing unit, light-emitting diode curing unit, temperature rise

Citation: Yazici AR, Müftü A, Kugel G. Temperature Rise Produced by Different Light-curing Units through Dentin. J Contemp Dent Pract 2007 November; (8)7:021-028.

Introduction

Light-cured composite resins are the most commonly used restorative materials in dentistry. One primary objective during operative procedures is the preservation of pulpal health. Polymerization of light-activated composites results in a temperature rise due to the exothermic reaction process and the energy absorbed during irradiation, despite proper use of light curing units. It has been reported the temperature within composite resin alone might increase up to 20ºC or more during light-induced polymerization.[1,2] The dental pulp can withstand small temperature changes from 37ºC to 42ºC for relatively short periods without permanent damage. The microcirculation of the pulp transports the heat entering the pulp away to other parts of the body where it is dissipated easily. However, extreme temperature changes or extended times of exposure to high temperatures will cause pulpal changes.[3]



Quartz-tungsten-halogen (QTH) curing units have been widely used to polymerize resin composites for many years. However, these curing units have some inherent limitations such as degradation of the halogen bulb, reflector, and the filter.[4] Within the past few years several new polymerization concepts and curing units have been introduced to the dental profession. Recent developments have focused on providing units with various irradiation protocols such as soft-start polymerization.

The soft-start polymerization technique involves a step-wise modulation of light energy from low to high intensities that facilitates greater flow and stress relief in the composite material.[5,6] Use of light emitting diode (LED) curing units has also been increasing. In contrast to QTH curing units, they do not require filters to produce light in the 400 to 500-nm range to excite camphoroquinone photoinitiators. They also produce less heat, which is considered a significant advantage over conventional halogen light curing units.[7] Since concerns have been raised curing lights may induce a temperature rise detrimental to the vitality of the dental pulp, the purpose of this study is to examine the temperature rise caused by different light curing units and to examine the temperature increase in dentin of different thicknesses.

Methods and Materials

The experimental setup consisted of the following:

- **Measurement of temperature changes caused by the light curing unit alone.**
  The tips of light curing units were covered with Mylar strips. The temperature was recorded directly at the surface of the light guide tip using a K-type thermocouple (Pyrometer, Windsor, NJ, USA). The mylar strips were discarded after each light polymerization.

- **Measurement of temperature changes based on dentin thickness.**
  Dentin discs of 1.0 and 2.0 mm thicknesses were prepared from mandibular molars embedded in Teflon molds with epoxy resin. The discs were sectioned perpendicular to the long axis of the tooth with a slow-speed saw (Buehler Ltd., Lake Bluff, IL, USA) and were kept in distilled water until they were used. A

mylar strip was placed over the dentin discs and they were irradiated from the top through the matrix using one of the curing lights tested. Temperature was recorded using a K-type thermocouple in direct contact with the dentin discs.

- **Measurement of temperature changes on varying thicknesses of dentin samples with cured composite using various light curing units.**
  A cured composite resin sample (Herculite XRV A2, Kerr Corporation, Orange, CA, USA) 2 mm in thickness was used in combination with dentin discs of 1 and 2 mm. After the composite sample was placed over the dentin disc, it was covered with a Mylar strip and irradiated from the top. Temperature changes were recorded as described earlier, using a thermocouple.

All measurements were performed by the same investigator.

Two QTH light curing units (Spectrum 800, Dentsply Caulk, Milford, DE, USA; Elipar Trilight, 3M-ESPE, St. Paul, MN, USA) and one LED curing unit (Elipar Freelight, 3M-ESPE, St. Paul, MN, USA) were used in this study (Table 1).

The intensity of curing units was checked with a radiometer before starting the experiment, and the curing times used were those recommended by the manufacturers.

Ten measurements were made for each curing unit and curing protocol (Table 1). Exposures of 40 seconds were used in each case, and the temperature was allowed to return to the ambient 25ºC between each repetition.

One-way analysis of variance (ANOVA) and the Scheffe's post-hoc test were used to determine differences in mean temperature rise among various curing lights and curing protocols. Differences between curing units were evaluated for each curing protocol separately and vice versa, using Scheffe's test at a significance level of $P<0.05$.

Results

The results of the temperature data are presented in Table 2. For all curing lights/modes, the highest temperature rises were observed under a Mylar strip during QTH irradiation in the standard mode (8.30ºC). Significant differences were observed among all curing lights under the mylar strip except between the QTH Spectrum and the ET in exponential mode ($p<0.05$).

Table 1. Light curing units used in this study.

LCU	Manufacturer	Curing Modes	Curing profile		
Spectrum 800 (Halogen)	Dentsply Caulk Milford, DE, USA	Standard	550 mW/cm^2 (40 seconds)		
Elipar Trilight (Halogen)	3M-ESPE St. Paul, MN, USA	Standard	800mW/cm^2 (40 seconds)		
		Exponential	100-800mW/cm^2 (15 seconds)	—	800mW/cm^2 (25 seconds)
Elipar Freelight (LED)	3M-ESPE St. Paul, MN, USA	Standard	400mW/cm^2 (40 seconds)		

Table 2. Mean values and standard deviations of temperature rise (°C) induced by different light curing units (LCU).

	Spectrum	LED	Trilight Standard	Trilight Exponential
Mylar	6.05 (0.25)^{a}	4.02 (0.16)^{b}	8.30 (0.59)^{c}	6.35 (1.16)^{a}
1 mm dentin	3.79 (0.30)^{d}	1.86 (0.19)^{e}	4.65 (0.30)^{f}	3.80 (0.32)^{d}
1 mm dentin cured composite	1.21 (0.24)^{j}	0.26 (0.16)^{k}	2.10 (0.51)^{l}	1.17 (0.22)^{j}
2 mm dentin	2.49 (0.90)^{g}	0.84 (0.07)^{h}	3.5 (0.09)^{i}	2.55 (0.16)^{g}
2 mm dentin cured composite	0.71 (0.16)^{m}	0.03 (0.05)^{n}	1.31 (0.36)^{m}	1.07 (0.40)^{m}

Note: For each horizontal row (i.e., comparison between different curing units for each condition), groups having the same letter superscripts are not significantly different ($p>0.05$). For each vertical column (comparison among different conditions in the same curing unit) in blue shaded areas are not significantly different ($p>0.05$).

Under 1 and 2 mm thick dentin barriers, the lowest temperature rise was measured for the LED and was followed by the QTH Spectrum and ET in exponentional mode. While there was no statistical difference between QTH Spectrum and ET in exponentional mode beneath 1 and 2 mm dentin, the differences were significant between the rest of the curing lights/modes under a 1 and 2 mm dentin barrier.

When measured under a 1 mm thick dentin barrier with a combination of cured composite with 2 mm in thickness, significant differences in temperature rise were found for all curing units except between the QTH Spectrum and ET in exponential mode. Mean temperature rises were insignificant between the QTH Spectrum and ET exponential mode and between two curing modes of Trilight when the same experimental setup was performed under a 2 mm thick dentin barrier with a combination of cured composite.

For all light curing units, temperature elevation through 2 mm of dentin was less than for a 1 mm of dentin thickness; all differences were significant ($p<0.05$).

For all tested conditions, ET standard mode produced the highest and LED produced the lowest temperature rise.

Discussion

In the present study, three different conditions were simulated: the direct temperature rise when curing through a mylar strip only, temperature rise through different dentin thicknesses; and through dentin with a combination of a cured composite. In an animal study Zach and Cohen[8] reported irreversible damage occurred when the temperature within the pulp chamber rose by 5.5°C. However, in a study conducted in human premolar teeth scheduled for extraction Baldissara et al.[9] showed human teeth could withstand an average increase of 11.2°C in pulpal temperature without any histological evidence of damage. In the present study, the highest temperature rise was observed under Mylar strips in direct contact with light curing units. Even in this worse case scenerio, the temperature did not exceed the threshold temperature of 11.2°C described by Baldissara et al.[9] for any of the curing units tested.

The amount of heat generated by curing units is related to the wavelength and power density of the light emitted. The results of the present study indicate the temperature rise observed with a LED curing unit was significantly lower than halogen lights for all test conditions. The highest temperature rise was observed with the ET in standard mode. This unit had the highest light output among the curing units evaluated. This finding is in agreement with previous studies and concludes LED curing units create a much smaller temperature rise than do QTH lights.[10,11,12]

When the Trilight was used in the exponential mode instead of the standard mode, a lower temperature rise was observed. Our results concur with those of Yap and Soh[7] and Uhl et al.[10] who found significant differences in temperature rise among different curing modes of ET. Uhl et al.[10] observed statistically lower temperatures within the composite if the Trilight was used in the exponential mode and concluded the composite is exposed to less light energy than in the standard mode. This might be thought as a further advantage of exponential mode besides the reduced polymerization contraction stress of dental composites cured using the soft-start mode.

Thermal transfer to the pulp may further be affected by the shade of the composite material, its thickness, composition, curing time, and the residual dentin thickness.[13] As the tooth or resin composite thickness increases, there is an exponential decrease in light transmission.[14] For all tested curing units, the temperature elevation through 2 mm of dentin thickness was less than for 1 mm of dentin thickness and all differences were significant. The temperature rise through 1 mm of dentin was nearly double that found through 2 mm of dentin which suggests an inverse relationship between dentin thickness and temperature increase. In other words, dentin is an effective insulator.

Temperature rise during curing of light-activated composites is a result of a chemical reaction in the material itself as well as of the heat output from the light-curing units.[2] However, the most significant source of heat during polymerization of a light activated restorative is from the curing unit and not from the material itself.[15-16] Therefore, the reason for using a cured specimen in this study was to exclude the temperature rise caused by the polymerization process itself.

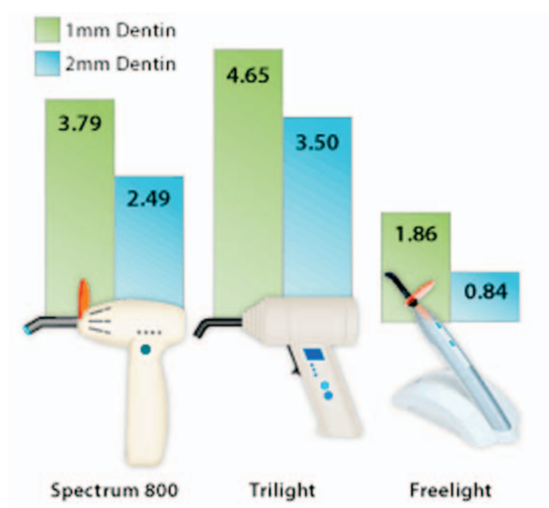
The decrease in temperature rise through cured composite/dentin specimens as the thickness increased is supported by previous studies.[17-18] The tooth molds and cured composites were prepared in a 2 mm thickness because of the recommendation composites should not be irradiated in increments greater than 2 mm thick.

The results of this study agree with another similar study in which it was shown the temperature increase was greatest when measured directly on the curing tip and least when measured through the combined composite/dentin sandwich.[19]

It might be speculated this *in vitro* experimental set up might overestimate the resultant temperature. The authors feel the temperature rise in pulp while using curing units during *in vivo* conditions will be lower because of the pulp tissues, its blood circulation, and the higher water content of the vital tooth structures. As a result, the type of light source and curing mode influence heat generation in light-cured systems. Moreover, the depth of tooth preparation should be taken into consideration when choosing the type of the curing unit.

Conclusion

For all curing units, temperature elevation through 2 mm of dentin was less than for 1 mm of dentin thickness. The ET standard mode produced the highest and the LED produced the lowest temperature rise for all tested conditions. The thickness of dentin and light-curing unit might affect temperature transmission.



References

1. Hofmann N, Hugo B, Klaiber B. Effect of irradiation type (LED or QTH) on photo-activated composite shrinkage strain kinetics, temperature rise, and hardness. Eur J Oral Sci 2002; 110(6):471-479.
2. Knezevic A, Tarle Z, Meniga A, Sutalo J, Pichler G, Ristic M. Degree of conversion and temperature rise during polymerization of composite resin samples with blue diodes J Oral Rehabil 2001; 28(6):586-591.
3. Bayne SC, Thompson JY, Taylor DF. Dental materials. Roberson TM, Heymann HO, Swift EJ, editors. Sturdevant's Art and Science of Operative Dentistry 4th ed. St.Louis: Mosby; 2000: 340-342.
4. Nomoto R, McCabe JF, Hirano S. Comparison of halogen, plasma and LED curing units. Oper Dent 2004; 29(3):287-294.
5. Burgess JO, DeGoes M, Walker R, Ripps AH. An evaluation of four light-curing units comparing soft and hard curing. Prac Perio Aesthet Dent 1999; 11(1):125-132.
6. Manhart J, Garcia-Godoy F, Hickel R. Direct posterior restorations: clinical results and new developments. Dent Clin N Am 2002; 46(2):303-339.
7. Yap AUJ, Soh MS. Thermal emission by different light-curing units. Oper Dent 2003; 28(3):260-266.
8. Zach L, Cohen G. Pulp response to externally applied heat. Oral Surg Oral Med Oral Pathol 1965; 19(4):515-530.
9. Baldissara P, Catapano S, Scotti R. Clinical and histological evaluation of thermal injury thresholds in human teeth: A preliminary study. J Oral Rehabil 1997; 24(11):791-801.
10. Uhl A, Mills RW, Jandt KD. Polymerization and light-induced heat of dental composite cured with LED and halogen technology. Biomaterials 2003; 24(10):1809-1820.
11. Ozturk B, Ozturk AN, Usumez A, Usumez S, Özer F. Temperature rise during adhesive and resin composite polymerization with various light curing sources. Oper Dent 2004; 29(3):325-332.
12. Yazici AR, Muftu A, Kugel G, Perry R. Comparison of temperature changes in the pulp chamber induced by various light curing units, in vitro. Oper Dent 2006; 31(2):261-265.
13. Goodis HE, White JM, Andrews J, Watanabe L. Measurement of temperature generated by visible-light-cure lamps in an in vitro model. Dent Mater 1989; 5(4):230-234.
14. Price RBT, Murphy DG, Derand T. Light energy transmission through cured resin composite and human dentin. Quintessence Int 2000; 31(9):659-667.
15. Masutani S, Setcos LC, Schnell RJ, Phillips RW. Temperature rise during polymerization of visible light-activated composite resins. Dent Mater 1988; 4(4):174-178.
16. Shortall AC, Harrington E. Temperature rise during polymerization of light-activated resin composites. J Oral Rehabil 1998; 25(12):908-913.
17. Tjan AHL, Dunn JR. Temperature rise produced by various visible light generators through dentinal barriers. J Prosthet Dent 1988; 59(4):433-438.
18. Smail SR, Patterson CJ, Mclundie AC, Strang R. In vitro temperature rises during visible-light curing of a lining material and a posterior composite. J Oral Rehabil 1988; 15(4):361-6.
19. Loney RW, Price RBT. Temperature transmission of high-output light- curing units through dentin. Oper Dent 2001;26(5): 516-520.

About the Authors

A. Rüya Yazici, DDS, PhD

Dr. Yazici is an Associate Professor in the Department of Conservative Dentistry of the Faculty of Dentistry at Hacettepe University in Ankara, Turkey. Her research interests include adhesive systems and composite resins.

e-mail: ruyay@hacettepe.edu.tr

Ali Müftü, DMD, MS

Dr. Müftü is an Associate Professor in the Department of Restorative Dentistry of the School of Dental Medicine at Tufts University in Boston, MA, USA.

Gerard Kugel, DMD, MS, PhD

Dr. Kugel serves as the Associate Dean for Research and is a Professor in the Department of Restorative Dentistry of the School of Dental Medicine at Tufts University in Boston, MA, USA. He is a Fellow in the American and International Colleges of Dentistry as well as the Academy of General Dentistry and the Academy of Dental Materials.