Dental Research Journal

Original Article

Kinetics of pulpal temperature rise during light curing of 6 bonding agents from different generations, using light emitting diode and quartz-tungsten-halogen units: An *in-vitro* simulation

Najmeh Khatoon Khaksaran[1], Tahereh Jafarzadeh Kashi[2], Vahid Rakhshan[3], Zahra Sadat Zeynolabedin[1], Hossein Bagheri[4]

[1]Department of Dental Biomaterials, Tehran University of Medical Sciences, [2]Iranian Tissue Bank and Research Center, Department of Dental Materials, Faculty of Dentistry, Research Center for Sciences and Technology in Medicine, Tehran University of Medical Sciences, [3]Iranian Tissue Bank and Research Center, Tehran University of Medical Sciences, Department of Dental Anatomy and Morphology, Dental Branch, Islamic Azad University, [4]Department of Dental Biomaterials, School of Dentistry and Research Center for Science and Technology in Medicine, Tehran University of Medical Sciences, Tehran, Iran

ABSTRACT

Background: Application of bonding agents (BA) into deep cavities and light curing them might increase pulpal temperature and threaten its health. The purpose of this study was to evaluate temperature rise of pulp by light curing six BA using two different light curing units (LCU), through a dent in wall of 0.5 mm.

Materials and Methods: This *in vitro* experiment was carried out on 96 slices of the same number of human third molars (6 BAs × 2 LCUs × 8 specimens in each group). There were 6 groups of BAs: N Bond, G-Bond, OptiBond XTR, Clearfil SE, Adper Single Bond 2 and V Bond. Each group of BA ($n = 16$) had two subgroups of light emitting diode (LED) and quartz-tungsten-halogen light cure units ($n = 8$). Each of these 16 specimens were subjected to light emitting for 20 s, once without any BAs (control) and later when a BA was applied to surface of disk. Temperature rises in 140 s were evaluated. Their mean temperature change in first 20 s were calculated and analyzed using two-way repeated-measures and one-way analysis of variance (ANOVA) and Tukey ($\alpha = 0.05$). Furthermore rate of temperature increase was calculated for each material and LCU.

Results: Minimum and maximum temperature rises in all subgroups were 1.7 and 2.8°C, respectively. Repeated measures ANOVA showed that both of adhesive and LCU types had significant effect on temperature rise after application of adhesives. Tukey *post-hoc* analysis showed Clearfil SE showed significantly higher temperature rise in comparison with Adper Single bond 2 ($P = 0.047$) and N Bond ($P = 0.038$). Temperature rose in a linear fashion during first 30-40 s and after that it was non-linear.

Conclusion: 20 s of light curing seems safe for pulpal health (with critical threshold of 5.5°C). However, in longer durations and especially when using LED units, the process should be broken to two sessions.

Key Words: Composite resins, dental materials, differential thermal analysis, polymerization

Received: December 2013
Accepted: February 2014

Address for correspondence:
Dr. Hossein Bagheri,
Department of Dental
Biomaterials, Research
Center for Science and
Technology, School of
Dentistry, Tehran University
of Medical Sciences, Amir
Abad Street, Tehran, Iran.
E-mail: dr.hbagheri@
gmail.com

INTRODUCTION

A healthy dental pulp plays a crucial role in maintaining health and integrity of tooth. Several factors however can endanger health of dental pulp, among which temperature rise is one of the most important ones.[1] A small increase in pulpal temperature can cause inflammatory reaction, histopathological

Access this article online

Website: http//:drj.mui.ac.ir

changes, vascular damage and cell death, in a way that about 5.5, 11 and 16°C can devitalize 15%, 60% and 100% of pulp cells respectively.[2-6] Therefore, this is a concern in dental treatments.[7]

A source of pulpal temperature is practicing restoration with resinous materials. Two factors contribute to thermal increase during setting of resinous materials. One is exothermic polymerization of resin monomers, which can increase pulp temperature up to 5.5°C.[6,8,9] This depends on the degree of conversion (DC) of used composite,[9-11] as well as size of restoration and thickness of intermediate dentin (which should not be less than 1 mm).[11,12] The DC is ratio of single carbon-carbon bonds in a polymer structure to double carbon-carbon bonds among monomers.[9,13] It indicates the polymerization extent.[9,11,14]

The other factor is light-curing. Light curing might increase temperature up to 6°C, which might be still tolerable by tissues.[15] These include light wavelength and intensity,[16] curing duration,[10] distance of light curing and type of light curing unit (LCU).[17,18] Two light-curing systems are used to initiate polymerization reaction. These systems include conventional quartz-tungsten-halogen (QTH) lamps and solid-state light emitting diodes (LED). The absorption wavelength of activator matches the wavelength of QTH light output. On the other hand, novel LED units are developed based on targeting the peak absorption wavelength of activator, by emitting a relatively narrow-band light at 430-480 nm. LEDs are becoming increasingly popular in dental practice.[19] They do not generate infrared wavelengths and have a constant light output.[19] Therefore, they might cause less pulpal temperature rise than QTH units.[20] However, this is controversial and some authors have stated that LEDs can produce as much heat as QTH lamps do.[21]

Such temperature rises can endanger pulpal health, since a 5.5°C increase in pulp temperature would cause about 15% pulpal non-vitality.[6] Due to their proper esthetics and function, light-curable composites are widely accepted in dental practice. Therefore, it is of significant importance to determine potential temperature rises after usage of materials (different composites and LCUs). Nevertheless, thermal characteristics of composites and especially bonding agents (BA) are largely unknown.[10,15,22]

Considering the importance of the subject, lack of studies on thermal characteristics of BA,[15,22] and controversy over heat generated by LEDs,[21] this study was conducted. Its aim was to assess the heat generated by six brands of composite BA cured by LED and QTH measured using a thermograph through a 0.5 mm dentin layer.

MATERIALS AND METHODS

This *in vitro* experimental study was performed on 96 sections of 96 intact extracted human third molars.

Sample preparation

Private dental clinics were attended to collect extracted third molars. A total of 96 intact teeth were stored in 0.2% thymol solution for 48 h and afterward were placed in distilled water for minimum 6 h until next step. The number of teeth was determined 96 samples in 6 groups of BA by 2 groups of LCUs by 8 specimens in each group in order to obtain a test power of 90% or greater, based on results of Dogan *et al*.[20]

Sectioning the teeth to prepare dentin disks

Teeth were removed from water and were fully merged in self-curable poly methyl methacrylate resin blocks (Acropars, Marlik, Iran). Transverse sections, 0.5 mm thin, were prepared from blocks, using Isomet Saw (Buehler Ltd., IL, USA) under water cooling in Isomet. The thickness of cuts was calibrated beforehand, using a micrometer with 1 micron sensitivity (Mitutoya, Japan). The device blade was adjusted to cut tooth at a 90° angle. After crown of each tooth was fully sectioned, sections were explored until finding the first one with pulp horn sections on them [Figure 1]. The section before this section was included and the rest were excluded. The sections which were consisted of inner dentin were evaluated regarding their thickness and angle of cut.

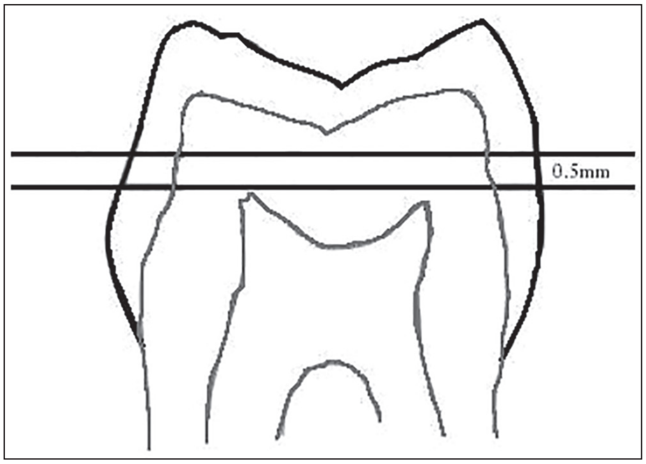

Figure 1: Schematic illustration of the closest intact slice to the pulp

BA

Six BA used in this study are fully described in Table 1.

Preparing bonded dentin disks

The experiments were carried out at a constant temperature (37°C). Each dentin disk was held on a flat disk-shape K thermocouple probe with 0.1°C accuracy (Testo, Testo AG, Lenzkirch, Germany). The thermocouple was connected to computer using a data logger, which allowed recording probe temperature in real time.

Light curing

The non-bonded dentin disks were first light cured for 140 s and temperature rise was recorded. The time of illumination was selected regarding to our pilot experiment which showed that all samples (after application of adhesives) reached the maximum temperature far below this time. The specimens before applying BAs acted as control and the same specimens after applying BAs acted as experimental cases. Any inconsistent specimen was excluded from the study and replaced with a new disk made from a fresh tooth. The adhesives were then applied to the other surface of dentin disks, in a random order (according to manufacturers). One half of 16 specimens of each BA group were cured using LED (BluePhase, Ivoclar Vivadent, Schaan, Liechtenstein) at 1200 mW/cm^2 intensity and the rest using QTH units (Blue Pass-T, Arialux, Tehran, Iran) at 750 mW/cm^2 intensity. These light intensities were set by manufacturers. Light output of QTH and LED was calibrated using a radiometer (Optilux model 100, 10503, Kerr, USA) to meet manufacturers' recommended values. Light curing was done with both units and temperature rise was recorded in 140 s. The same specimens before application of BA were subjected to light curing with a similar protocol and their temperature rise was recorded as the control values.

Statistical analysis

The recorded temperatures in time were used to calculate mean temperature rises in different groups (2 LCUs, 6 BAs and with or without BA) during the first 20 s (as the time routinely considered for polymerization of BAs). The effects of BA and LCUs were assessed using two-way repeated-measures analysis of variance (ANOVA). Since the interactions were significant, one-way ANOVA along with a Tukey *post-hoc* test was used as well to compare adhesives and light cure units. Statistical analyses were performed using SPSS program (SPSS Inc., IL, USA). $P \leq 0.05$ were considered to be significant.

The collected data were also used to draw the curves of temperature rise within 140 s. These curves were used to estimate the thermal equilibrium and kinetics of temperature rises caused by each of the materials plus each light curing device and also by each LCU alone. The temperature curves have two parts. First,

Table 1: The used BA

Brand	Composition	Manufacturer	Properties	Recommended light curing time	Lot number
N Bond	Phosphoric acid acrylate, HEMA, BisGMA, urethane dimethacrylates, ethanol, film forming agent, catalysts, stabilizers	Ivoclar Vivadent, Schaan, Liechtenstein	Etch and rinse – Single bottle (5th generation)	≥500 mW/cm^2 20 s ≥1,000 mW/cm^2: 10 s	N76256
G-Bond	4-meat, TEGDMA, UDMA, acetone, water, initiator	GC-USA	Self-etch, single bottle, single step (7th generation)	Halogen/LED (700 mW/cm^2): 20 s (1200 mW/cm^2): 10 s	1006231
OptiBond XTR	Primer: GPDM, HEMA, dimethacrylate, photoinitiator, water, ethanol, acetone Adhesive: Bis-GMA, HEMA, tri-functional monomer, ethanol, photoinitiator, barium glass filler, fluoride-containing filler, nano-filler	Kerr-USA	Self-etch, two bottle (6th generation)	5-20 s according to the light curing unit manufacturer's recommendation	Primer: 3562882 Adhesive: 3562883
Clearfil SE	MDP, HEMA, bis-GMA, hydrophobic dimethacrylates, submicron silica fillers, N, Ndiethanol-p-toluidine, CQ	Ivocolar Vivadent, Schaan, Liechtenstein	Self-etch, two bottle (6th generation)	The recommended light curing time is 10 s	Primer: 01039A Adhesive: 01550A
Adper Single Bond 2	bis-GMA, HEMA, dimethacrylates, polyalkenoic acid copolymer, initiators, water and ethanol	3M/ESPE-USA	Etch and rinse – Single bottle (5th generation)	The recommended light curing time is 10 s	N246651
V Bond	bis-GMA, HEMA, dimethacrylates, polyalkenoic acid copolymer, initiators, water and ethanol	Temrex-USA	Etch and rinse – Single bottle (5th generation)	Not available	110105

TEGDMA: Triethylene glycol dimethacrylate; UDMA: Urethane dimethacrylate; GPDM: Glycerol phosphate dimethacrylate; HEMA: Hydroxyethylmethacrylate; bis-GMA: Bisphenol-glycidyl methacrylate; MDP: Methacryloyloxydecyl dihydrogen phosphate; CQ: Camphorquinone; LED: Light emitting diode the temperature increase is linear. After some time, it becomes a non-linear, such that the rate of temperature rise decreased as the function of time. Therefore, in the first part (when the function is linear), it is possible to estimate temperature changes by dividing the first maximum temperature by the passed time needed to reach that temperature:

Rate of temperature rise in the linear part$_{(°C/S)}$ = Max $(\Delta t_1)_{(°C)}/t_{1(S)}$

(t_1 is the time point of the first maximum temperature).

In the second part, it is possible to estimate the temperature changes by dividing the temperature rise in the second part by the elapsed time.

Rate of temperature rise in the non-linear part $_{(°C/S)}$ = $[\text{Max } (\Delta t_2)_{(°C)} - \text{Max } (\Delta t_1)_{(°C)}/t_2 - t_1]_{(S)}$

RESULTS

Temperature rise on control dentin disks

Two-way ANOVA analysis for the data obtained without the application of adhesives showed that there was no significant difference between the mean values for heat rises of BAs cured by two LCUs ($P = 0.14$) and between the 6 groups ($P = 0.6$).

Temperature rise on BA-coated dentin disks

When the heat sources were both LCUs and BA pasted onto the disk surfaces, ANOVA showed a difference between the adhesives ($P = 0.04$). However, Tukey test did not find a significant difference between the BA, compared one by one.

Temperature rise before and after application of adhesives in the first 20 s

Repeated measures ANOVA procedure showed that both of the adhesive and LCU types had significant effect on the temperature rise after application of adhesives. The Tukey *post-hoc* analysis revealed that Clearfil SE showed significantly higher temperature rise in comparison with Adper Single bond 2 ($P = 0.047$) and N Bond ($P = 0.038$) [Table 2, Figures 2 and 3].

Repeated measures ANOVA procedure for each group showed that the effect of LCUs was only significant in Adper Single bond 2 ($P = 0.008$).

Thermal equilibrium

The temperature changes during the elapsed time are shown in Table 3 and Figure 4. The findings showed that LED units had higher maximum temperatures

Table 2: Mean and standard deviations of temperature rise within 20 s of light curing, in different experimental groups

BA	LCU	Temperature rise without BA	Temperature rise with BA	*P* value
Adper Single bond 2	QTH	1.86 (0.23)	2.15 (0.18)	0.008
	LED	1.81 (0.1)	2.4 (0.15)	
Clearfil SE-bond	QTH	2.02 (0.36)	2.60 (0.49)	0.51
	LED	2 (0.4)	2.8 (0.45)	
V Bond	QTH	1.72 (0.13)	2.29 (0.22)	0.78
	LED	1.9 (0.25)	2.16 (0.31)	
G-Bond	QTH	2.01 (0.14)	2.61 (0.32)	0.63
	LED	1.84 (0.33)	2.63 (0.9)	
Optibond XTR	QTH	1.86 (0.21)	2.2 (0.5)	0.28
	LED	2.3 (0.38)	2.7 (0.54)	
N Bond	QTH	1.7 (0.26)	2.08 (0.63)	0.05
	LED	1.82 (0.45)	2.59 (0.28)	

BA: Bonding agent; LCU: Light curing unit; QTH: Quartz-tungsten-halogen; LED: Light emitting diode

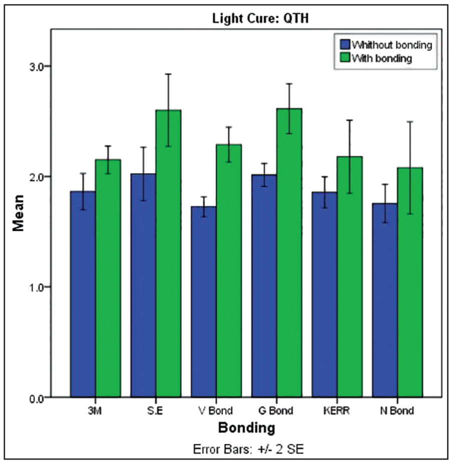

Figure 2: Temperature rises of different adhesives before and after application of bonding agents, all cured by quartz-tungsten-halogen unit

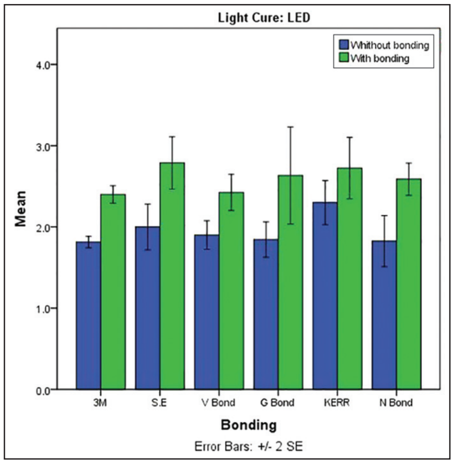

Figure 3: Temperature rises of different adhesives before and after application of bonding agents, all cured by light emitting diode unit

Table 3: Estimation of rate of temperature rise for different BA (only experimental groups), based on times elapsed to reach maximum temperatures

BA	LCU	Max (Δt_1) (°C)	Elapsed time to reach Max 1 (t_1) (s)	Max (Δt_2) (°C)	Elapsed time to reach Max 2 (t_2) (s)	Linear temp. rise rate (°C/s)	Non-linear temp. rise rate (°C/s)
Adper Single Bond 2	QTH	2.1	20	3.8	63	0.1	0.04
	LED	2.4	20	8.8	90	0.12	0.09
Clearfil SE-Bond	QTH	3.2	25	6.1	135	0.13	0.03
	LED	5.8	40	7.9	125	0.14	0.02
V Bond	QTH	2.3	22	4.5	95	0.1	0.03
	LED	3.1	21	7.2	100	0.15	0.05
G-Bond	QTH	2.6	20	3.8	65	0.13	0.03
	LED	5.2	38	8.6	100	0.14	0.05
Optibond	QTH	3.1	25	5.2	75	0.12	0.04
	LED	5.6	35	9.2	95	0.16	0.06
N Bond	QTH	2.08	20	4.7	77	0.1	0.03
	LED	3.4	23	6.3	80	0.15	0.05

BA: Bonding agent; LCU: Light curing unit; QTH: Quartz-tungsten-halogen; LED: Light emitting diode

in both first (linear) and second (non-linear) parts [Figure 4]. They had also higher rates of heating in the first part, but not in the second part.

DISCUSSION

The study findings showed that none of evaluated BA polymerized using any of the light curing devices reached a dangerous level of temperature rise (at least 5.5°C for 15% of pulpal necrosis).[6] Therefore, used light intensities with both devices seem safe with the different groups of adhesives. These results were in agreement with Dogan *et al*.[20] and Pereira Da Silva *et al*.[23] who did not find a damaging temperature of BA cured using QTH and LED units.

The evaluated materials showed a significant difference, which could be due to their different viscosities, different amounts of free radicals, their optimized setting temperatures, etc.[9,13,14,24-26] It should be noted that composition of the materials were arranged in a way that besides proper characteristics, it can be set with a high DC. Therefore, since DCs of different materials were at the highest possible limit, their differences were reduced.

Although, the results of the present study was in agreement with some studies,[27-30] it was in contrast to some other articles reporting QTH units as more heat generating than LEDs and plasma arch units.[12,20,23,31] QTH lamps might produce more heat since their lamps emit a much broader range of wavelengths, many of which convert to heat.[31] The controversy might be due to differences in light intensity irrespective of emitted wavelength. It was shown that when LED's intensity was higher than QTH, generated heat would be higher and light intensity seems the main factor.[27-30] A higher light intensity is expected to increase the temperature more since more photons are absorbed by unit of area on tooth tissue. Besides, it might be capable of inducing more polymerization due to warming material and reducing its viscosity and therefore radical mobility, as well as increasing collision frequency of unreacted active groups and radicals.[9,13,14,24,25] The latter is confirmed and accentuated by our finding that in absence of BA, LED and QTH do not differ significantly, but after bonding, the temperature rise of LED increases significantly. On the other hand, Dogan *et al*.[20] used light intensities similar to this study. However, they reported greater produced heats by QTH (despite its lower intensity).[20] The reason can be their shorter time of light curing by LED (10 s for LED, 40 s for QTH).[20] Some other studies found LED to generate less curing heats,[12,23] which might be related to properties of composites/adhesives and wavelengths and intensities of LCUs.[20,32]

The significant superiority of LED in heat generating for four of BA within 20 s was not clinically considerable, because a fraction of Celsius degree does not seem to affect pulp health. It is less important when noticing the ability of healthy tissue in balancing the increased temperature through its arterioles and surrounding dentin which can disperse the heat away.[8,9,33] Therefore, it seems that these two devices are both safe in light curing restorations when the pulp is healthy, but problem is that in deep cavities, pulp condition is questionable and needs more caution. Traumatized and irradiated tissues as well as tissues

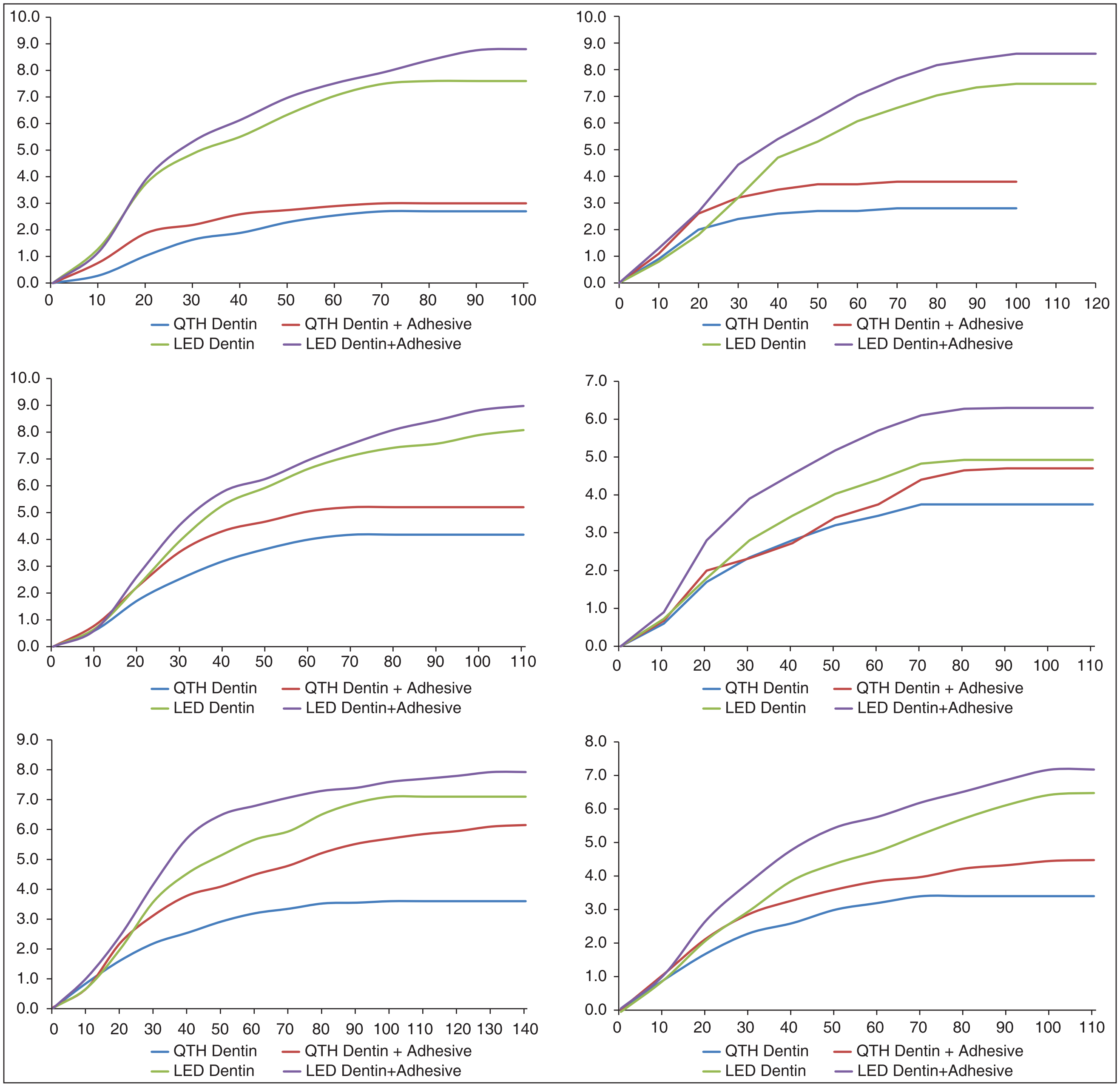

Figure 4: Temperature rises in all groups

in some medically compromised and elderly patients might be highly vulnerable to thermal irritations.[8,15]

This study was limited by some factors. Results of an *in vitro* study cannot be generalized to clinical situation with highly vascular periodontal and pulpal tissues, without further clinical assessments.[34] Furthermore, results of a brand cannot be generalized to other brands.[15] This is why we used several generations of adhesives from different manufacturers. On the other hand, method of measurement was accurate and allowed detection of small differences. Another limitation was that some materials needed blending, which exposed experiment to human error. However, we carefully selected teeth and cut them and excluded many specimens with inconsistent data in order to reduce many sorts of human error. In the current study, the high intensity for both QTH and LED devices was used in order to simulate the worst clinical situation regarding the pulpal temperature rise.

CONCLUSION

It might be concluded that the types of LCU did not differ, unless BA were applied. In presence of

BA, LED might induce more heat. The heat seems tolerable by tissue since temperature rise is not more than about 2 or 3°C during the first 20 s, which is below the critical threshold of pulp tolerance (5.5°C). According to our findings, if more than 20 s of light curing was needed, it is recommended to break the light curing into two sessions (each session 20s or less) to allow the pulp to cool down.

REFERENCES

1. Summitt J, Robbins J. Fundamentals of Operative Dentistry: A Contemporary Approach. 3rd ed. Chicago: Quintessence Publishing Co.; 2006. p. 24-6, 101-30.
2. Jost-Brinkmann PG, Stein H, Miethke RR, Nakata M. Histologic investigation of the human pulp after thermodebonding of metal and ceramic brackets. Am J Orthod Dentofacial Orthop 1992;102:410-7.
3. Langeland k, Langeland lk. Pulp reactions to crown preparation, impression, temporary crown fixation, and permanent cementation. J Prosthet Dent 1965;15:129-43.
4. Santamaria M Jr, Milagres D, Iyomasa MM, Stuani MB, Ruellas AC. Initial pulp changes during orthodontic movement: Histomorphological evaluation. Braz Dent J 2007;18:34-9.
5. Nyborg H, Brännström M. Pulp reaction to heat. J Prosthet Dent 1968;19:605-12.
6. Zach L, Cohen G. Pulp response to externally applied heat. Oral Surg Oral Med Oral Pathol 1965;19:515-30.
7. von Fraunhofer JA, Allen DJ. Thermal effects associated with the Nd/YAG dental laser. Angle Orthod 1993;63:299-303.
8. Driscoll CF, Woolsey G, Ferguson WM. Comparison of exothermic release during polymerization of four materials used to fabricate interim restorations. J Prosthet Dent 1991;65:504-6.
9. Jafarzadeh-Kashi TS, Mirzaii M, Erfan M, Fazel A, Eskandarion S, Rakhshan V. Polymerization behavior and thermal characteristics of two new composites at five temperatures: Refrigeration to preheating. J Adv Prosthodont 2011;3:216-20.
10. Mousavinasab SM, Khoroushi M, Moharreri M. Temperature Rise during Primer, Adhesive, and Composite Resin Photopolymerization of a Low-Shrinkage Composite Resin under Caries-Like Dentin Lesions. ISRN Dent 2012;2012:198351.
11. Antonucci JM, Toth EE. Extent of polymerization of dental resins by differential scanning calorimetry. J Dent Res 1983;62:121-5.
12. Rajesh Ebenezar AV, Anilkumar R, Indira R, Ramachandran S, Srinivasan MR. Comparison of temperature rise in the pulp chamber with different light curing units: An *in-vitro* study. J Conserv Dent 2010;13:132-5.
13. Prasanna N, Pallavi Reddy Y, Kavitha S, Lakshmi Narayanan L. Degree of conversion and residual stress of preheated and room-temperature composites. Indian J Dent Res 2007;18:173-6.
14. Cotti E, Scungio P, Dettori C, Ennas G. Comparison of the degree of conversion of resin based endodontic sealers using the DSC technique. Eur J Dent 2011;5:131-8.
15. Jafarzadeh Kashi TS, Erfan M, Rakhshan V, Aghabaigi N, Tabatabaei FS. An *in vitro* assessment of the effects of three surface treatments on repair bond strength of aged composites. Oper Dent 2011;36:608-17.
16. Mousavinasab SM, Meyers I. Comparison of depth of cure, hardness and heat generation of LED and high intensity QTH light sources. Eur J Dent 2011;5:299-304.
17. Santini A, Watterson C, Miletic V. Temperature rise within the pulp chamber during composite resin polymerisation using three different light sources. Open Dent J 2008;2:137-41.
18. Craig R, Ward M. Restorative Dental Materials. Ch. 3, 9. España: Elsevier; 2006. p. 40-8, 187-90.
19. Felix CA, Price RB, Andreou P. Effect of reduced exposure times on the microhardness of 10 resin composites cured by high-power LED and QTH curing lights. J Can Dent Assoc 2006;72:147.
20. Dogan A, Hubbezoglu I, Dogan OM, Bolayir G, Demir H. Temperature rise induced by various light curing units through human dentin. Dent Mater J 2009;28:253-60.
21. Santini A. Current status of visible light activation units and the curing of light-activated resin-based composite materials. Dent Update 2010;37:214-6, 218-20, 223-7.
22. Daronch M, Rueggeberg FA, Moss L, de Goes MF. Clinically relevant issues related to preheating composites. J Esthet Restor Dent 2006;18:340-50.
23. Pereira Da Silva A, Alves Da Cunha L, Pagani C, De Mello Rode S. Temperature rise during adhesive and composite polymerization with different light-curing sources. Minerva Stomatol 2010;59:253-8.
24. Faria-E-Silva AL, Piva E, Moraes RR. Time-dependent effect of refrigeration on viscosity and conversion kinetics of dental adhesive resins. Eur J Dent 2010;4:150-5.
25. Daronch M, Rueggeberg FA, De Goes MF. Monomer conversion of pre-heated composite. J Dent Res 2005;84:663-7.
26. Jafarzadeh Kashi TS, Erfan M, Kalbasi S, Ghadiri M, Rakhshan V. The effects of light curing units and environmental temperatures on C=C conversion of commercial and experimental bonding agents. Saudi Dent J 2014. ePub ahead of print. DOI: 10.1016/j.sdentj.2014.05.006. Available Online from: sciencedirect.com/science/article/pii/S1013905214000595.
27. Barakatain M, Malekipour M, A'laee S, Kavousi M. Temperature rise in dentin disks with different thickness and distances from the light cure unit tips using two different curing units. J Islam Dent Assoc 2012;24:217-24.
28. Guiraldo RD, Consani S, Lympius T, Schneider LF, Sinhoreti MA, Correr-Sobrinho L. Influence of the light curing unit and thickness of residual dentin on generation of heat during composite photoactivation. J Oral Sci 2008;50:137-42.
29. Millen C, Ormond M, Richardson G, Santini A, Miletic V, Kew P. A study of temperature rise in the pulp chamber during composite polymerization with different light-curing units. J Contemp Dent Pract 2007;8:29-37.
30. Durey K, Santini A, Miletic V. Pulp chamber temperature rise during curing of resin-based composites with different light-curing units. Prim Dent Care 2008;15:33-8.
31. Yap AU, Soh MS. Thermal emission by different light-curing units. Oper Dent 2003;28:260-6.
32. Pilo R, Oelgiesser D, Cardash HS. A survey of output intensity

and potential for depth of cure among light-curing units in clinical use. J Dent 1999;27:235-41.

33. Bagheri J, Sarabi N. Temperature rise of dental pulp associated with composite application with a fixed light curing. J Mashhad Dent Sch 1999;23:111-8.
34. Khosravanifard B, Yazdani R, Rakhshan H, Rakhshan V. The effect of acidulated phosphate fluoride incorporated phosphoric acid etchant on shear bond strength of orthodontic brackets. Dent Res J (Isfahan) 2011;8:183-8.

How to cite this article: Khaksaran NK, Kashi TJ, Rakhshan V, Zeynolabedin ZS, Bagheri H. Kinetics of pulpal temperature rise during light curing of 6 bonding agents from different generations, using light emitting diode and quartz-tungsten-halogen units: An *in-vitro* simulation. Dent Res J 2015;12:173-80.

Source of Support: This study was supported by the Tehran University of Medical Sciences (Grant Number 19951). The grant was funded by the Razi Festival as an award to Dr. Vahid Rakhshan. **Conflict of Interest:** None declared.