

# Temperature Rise During Orthodontic Bonding With Various Light-curing Units—An In Vitro Study

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## ABSTRACT

The purpose of this in vitro study was to investigate the temperature changes in the pulp chamber during bracket bonding using three different light sources. Bracket bonding was performed on one lower first premolar and one lower central incisor at two different distances (surface and 10 mm). The measurements were taken with a J-type thermocouple wire, placed in the pulp chamber and connected to a data logger. Analysis of variance revealed that pulp chamber temperature changes were influenced by the light source, the tooth type, and the distance from the tip of the light guide to the bracket surface. Halogen induced significantly higher intrapulpal temperature changes than light-emitting diode and Xenon Plasma Arc (PAC) ( $P = .000$ ). The temperature increase was significantly higher when the light-guide tip was positioned at the surface of the teeth than at the 10-mm distance with all light-curing units ( $P = .000$ ). All light-curing units produced higher intrapulpal temperature increase in the mandibular incisor than in the premolar. Power PAC produced significantly higher heat changes in the incisor than in the premolar. Orthodontic bonding with different light-curing units did not exceed the critical 5.5°C value for pulpal health. (*Angle Orthod* 2006;76:330–334.)

**KEY WORDS:** Temperature rise; Pulp chamber; Orthodontic bonding; Light curing

## INTRODUCTION

The light-initiated resins have become the most popular adhesives for a majority of orthodontists because of the reduced contamination risk, accurate bracket placement, and easier excess adhesive removal during bonding.<sup>1–7</sup> In the 1990s, rapid light-curing alternatives for conventional halogen units, such as Quartz Tungsten Halogen (QTH), Xenon Plasma Arc (PAC), and the light-emitting diode (LED), were introduced in orthodontics, parallel with general dentistry.<sup>2–4,6–8</sup> However, concerns have been raised that these new cur-

ing lights may induce a temperature rise that could be detrimental to pulp vitality during photoactivation.

It is known that any increase in pulpal temperature exceeding 5°C to 6°C may result in irreversible tissue damage.<sup>9</sup> Previous in vitro studies have shown the thermal effect of different light sources in general dentistry.<sup>10–16</sup> Goodis et al<sup>17</sup> tested six visible light-curing units and found that the lamps do cause a temperature rise within the pulp chamber, and the longer the lamp is used, the higher the temperature rise. Hannig and Bott<sup>18</sup> used a Class II restorative preparation on a molar and measured the temperature changes in the pulp chamber with eight different curing units. Their findings indicate that the potential risk for heat-induced pulpal injury during composite resin polymerization is increased with the high-energy light sources when compared with the low-energy light-curing units. Powell et al<sup>16</sup> showed that in vitro pulp chamber temperature increase from laser units were significantly lower than that from the conventional curing lights. Tarle et al<sup>19</sup> measured the temperature rise in the composite samples with three different light sources, and because of very short exposure time, they found a slight temperature rise with the high-power plasma light.

Such investigations showed that heat generation may vary depending on the light source, exposure

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**TABLE 1.** Experimental Groups of the Study<sup>a</sup>

Group	Number of Measurements	Tooth Type	Light-curing Unit	Distance
I	5	Premolar	Halogen	Surface
II	5	Premolar	Halogen	10 mm
III	5	Premolar	LED	Surface
IV	5	Premolar	LED	10 mm
V	5	Premolar	PAC	Surface
VI	5	Premolar	PAC	10 mm
VII	5	Lower incisor	Halogen	Surface
VIII	5	Lower incisor	Halogen	10 mm
IX	5	Lower incisor	LED	Surface
X	5	Lower incisor	LED	10 mm
XI	5	Lower incisor	PAC	Surface
XII	5	Lower incisor	PAC	10 mm

<sup>a</sup> LED indicates light-emitting diode; PAC, Xenon Plasma Arc.

time, composite resin thickness–related exothermic reaction, and the distance between the light source and the pulp.<sup>10,17,20,21</sup> However, there are several factors in restorative dentistry that vary from those in orthodontic bonding procedures.<sup>3</sup> First, in bonding orthodontic brackets or retainers, the distance from the pulp is greater because of the lack of any cavity on the insulating enamel. Second, the orthodontic attachments (brackets, tubes, etc) are present between the light sources and the enamel. Third, the adhesive layer is very thin, pressed between the bracket and the tooth.

Oesterle et al<sup>3</sup> carried out an unpublished pilot study and suggested using the xenon plasma light with short durations, especially on teeth that have thin enamel such as the lower incisors. However, the pulp temperature change after curing with different light sources and their effect on tooth type has not been investigated for orthodontic bonding procedures.

The aim of this in vitro study was to investigate the temperature changes in the pulp chamber of a premolar and a lower incisor during bracket bonding using three different light sources.

# MATERIALS AND METHODS

In this in vitro study, two different types of human teeth (premolar and lower incisor) were irradiated at two different distances (surface and 10 mm) with three visible light–curing units. Twelve experimental groups were prepared (Table 1). A single-root lower first pre-

molar and a lower central incisor were used in all experimental trials. Brackets (Omni Arch, GAC, Bohemia, NY) were bonded using Transbond XT (3M/Unitek, Monrovia, Calif) adhesive and light cured with Halogen light for 40 seconds, with LED light for 20 seconds, and with Plasma Arc light for five seconds. The light units and technical details are shown in Table 2.

Orthodontic bonding was performed without acid etching to enable an easy removal of the bracket and to avoid enamel loss during repeated debonding procedures. In a pilot study, we tested the effect of acid etching on the pulp chamber temperature changes. A different lower premolar was bonded five times with acid etching using the plasma arc, and surface and pulpal temperatures were measured as described above. The mean values of the temperature increases were  $1.11 \pm 0.21$  (with acid etching) and  $1.00 \pm 0.09$  (without acid etching, V group). Mann-Whitney *U*-test did not indicate statistically significant differences between both values. Therefore, all further measurements were taken without acid etching. Light exposures were performed according to the manufacturers' instructions (Table 2).

For temperature measurements, the roots of the premolar and the incisor were resected and pulp residues were removed retrograde. A J-type 0.36-inch-diameter thermocouple wire (Omega Engineering Inc, Stamford, Conn) was inserted into the pulp chamber of the sample tooth to measure temperature changes. The thermocouple maintained contact with the dentin by a thin layer of silicone heat-transfer compound (ILC P/N 213414, Wakefield Engineering, Wakefield, Mass). Its position in the pulp chamber was checked radiographically. The root stub was then secured with a composite resin, and the sample tooth was mounted in the cover plate of a water bath ( $37 \pm 0.5^{\circ}\text{C}$ ) (Nuve, Ankara, Turkey). The thermocouple wire was connected to a data logger (XR440-M Pocket Logger, Pace Scientific, Mooresville, NC) during the bracket bonding procedure. Intrapulpal temperature changes were recorded every two seconds. The recordings were started at the same time with light curing and were ended when the temperature had started to drop from its maximum level. The collected data, available in both tabular and graphic form, were monitored in real time and transferred to a computer.

**TABLE 2.** Light Sources Used in the Study<sup>a</sup>

Light-curing Unit	Output of Light Tip (mW/cm <sup>2</sup> )	Diameter of Tip (mm)	Exposure Time (s)
Smart-lite Dental Curing Light (Benlioglu Dental Inc, Ankara, Turkey)	625	7	40
Ortholux LED Curing Light (3M/Unitek Orthodontic Products, Monrovia, Calif)	1100	8	20
Power PAC Plasma Curing Light (American Medical Technologies, Corpus Christi, Tex)	1200	7	5

<sup>a</sup> LED indicates light-emitting diode; PAC, Xenon Plasma Arc.

**TABLE 3.** Results of ANOVA Comparing Mean Values of Temperature Increases of Experimental Groups

Light-curing Unit	Tooth Type	Temperature Increase (°C)	
		Surface	10 mm
Halogen	Lower premolar	1.90 ± 0.09*§	0.91 ± 0.13*§
	Lower incisor	2.03 ± 0.30*§	1.03 ± 0.13*§
LED	Lower premolar	1.35 ± 0.10*§	0.52 ± 0.09*§‡
	Lower incisor	1.45 ± 0.29*§	0.78 ± 0.12*§‡
PAC	Lower premolar	1.00 ± 0.09*§‡	0.82 ± 0.18*§‡
	Lower incisor	1.58 ± 0.23*§‡	1.15 ± 0.14*§‡

<sup>a</sup> LED indicates light-emitting diode; PAC, Xenon Plasma Arc; ANOVA, analysis of variance.

\* Distance difference significant ( $P = .001$ ), Curing unit difference significant ( $P = .001$ ), Tooth type difference significant ( $P < .05$ ).

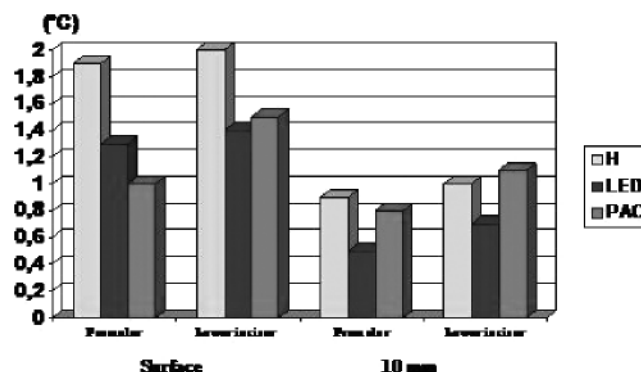
Five measurements were obtained from each group. The difference between the starting and the highest temperature readings was taken, and the five calculated temperature changes were averaged to determine the mean temperature increase. The light outputs of the curing units were checked before each testing procedure with a Hilux radiometer (Benlioglu Dental, Ankara, Turkey). Although the handheld radiometers measure the light output within a narrow band, this was used to measure the wavelengths considered effective for curing.<sup>22</sup> There was no measurable reduction in light intensity for any light during the experiment.

Analysis of variance (ANOVA) was performed to determine the effect of tooth type, light-curing unit, and distance on the temperature rise. The post hoc analyses were made using the least significant difference (LSD) test to determine which groups were significantly different. SPSS 10.1 (Chicago, Ill) was used for all statistical analyses in which  $P < .05$  was adapted as the critical significance level.

## RESULTS

Table 3 shows mean values, standard deviations, and the statistical significances of the temperature increase for all the three variables (light-curing unit, tooth type, and distance). The ANOVA and LSD tests revealed that pulp chamber temperature changes were influenced by the light-source type, tooth type, and the distance from the tip of the light guide to the bracket surface.

Halogen induced significantly higher intrapulpal temperature changes than did the LED and PAC ( $P = .000$ ). The difference between Halogen and PAC was statistically significant at all but the 10-mm distance. When the light-guide tip was positioned at the surface of the lower incisor, there was no statistically significant difference between LED and PAC. The lower incisor was affected more than the premolar, but the differences were statistically significant only with PAC at two distances ( $P < .001$ ) and with LED at the 10-mm distance ( $P < .05$ ). The temperature increased signif-



**FIGURE 1.** Temperature increases in the pulp chamber of the premolar and the incisor with three light sources at two distances.

icantly more at the surface than at the 10-mm distance with all light-curing units ( $P = .000$ ). The graphic presentation of the results is shown in Figure 1.

## DISCUSSION

The thermal effect of light sources is well known, but information about pulp chamber temperature changes during orthodontic bonding procedures is scarce. Publications in restorative dentistry showed that the direct comparison of the light sources' heat effect is very difficult, if not impossible, because of the great variability of investigated materials and exposure times. Tarle et al<sup>19</sup> found that high-power plasma light leads to lower temperature increases than do Halogen or LED in composite samples because of very short exposure time. However, the results of other studies showed that a light source with high-energy output (Plasma Arc Light) caused significantly higher temperature changes than with the low-energy output lights (Halogen and LED) under dentin disks.<sup>23,24</sup> Hofmann et al,<sup>11</sup> using "deflecting disc technique," recorded that the heating from radiation during polymerization was lower with LED light than with QTH.

Studies on pulpal heat changes were also different in several aspects. Weerakoon et al<sup>10</sup> examined the heat changes associated with standardized Class V restorations on the buccal surface of extracted pre-

molar teeth using a curing time of 40 seconds. They concluded that LED lights produced less thermal insult on dental pulp than did the halogen lamps. Hannig and Bott<sup>18</sup> studied Class II restorative preparations on a molar and recorded that the risk for heat-induced pulpal injury was increased using the high-energy light source (Plasma Arc Light) at 10 seconds as compared with the low-energy light-curing units (Halogen units) at 40 seconds.

In this study, we used an orthodontic bonding setup to mimic the clinical situation and found the effect of different energy outputs on dental pulp. The thermal effect on the pulp tissue depends on the variations in the enamel and dentin thickness of the pulp chamber wall.<sup>10,25</sup> Lower incisors exhibit a higher risk of thermal damage because of thinner enamel and dentin thickness on the labial side.<sup>21,26</sup> However, variations within each tooth can also affect the thermal response.<sup>25</sup> Accordingly, in this study only one lower premolar and one lower incisor were used to control the thickness of the labial pulp wall and to eliminate any possible structural differences.

To represent the clinical environment, the sample teeth were irradiated at a distance of 10 mm and at the surface.<sup>20</sup> Five measurements were obtained from each group. There was no need to increase the number of measurements because of the very low values of the standard deviations (Table 3).

Our results showed statistically significant differences among the three light-curing units tested (Table 3). Halogen with the longest exposure time induced significantly higher intrapulpal temperature changes than did the LED or PAC. These findings conflict with the concern of increasing heat-induced pulpal injury risk with high-energy output lights, but reveal the importance of exposure time.<sup>18,23,24</sup> The critical values reported for pulpal injury were not exceeded in any of the experiments of this study.<sup>9</sup> However, there are only a few in vivo studies available in the literature reporting on the critical values for pulp injury, and one should be careful in the interpretation of these findings.<sup>9,21,25</sup>

Comparison of tooth types revealed that the temperature increase was higher in the lower incisor than in the premolar with all three curing units. These findings were in accordance with the previous results.<sup>21,26,27</sup> Statistically significant differences were found only with the PAC at two distances and with the LED at 10 mm. The temperature increase was significantly higher at the closer distance with all light-curing units (Table 3).

However, the temperature values measured in this study cannot be directly applied to temperature changes in vivo. The design of this study did not consider heat conduction within the tooth because of the effect of blood circulation in the pulp chamber and fluid mo-

tion in dentin tubules.<sup>18</sup> In addition, the surrounding periodontal tissues can promote heat convection in vivo, limiting the intrapulpal temperature rise.<sup>27</sup> On the other hand, actual temperature increases might be higher in clinical conditions in younger teeth. Therefore, extensions to this study will consider a histological investigation of the human pulp to evaluate the effects of the light curing during orthodontic bonding in clinical conditions. Future histological investigations are needed to clarify the thermal threshold for pulpal injury, not just to investigate the effect of light curing but also after other orthodontic procedures such as stripping, reshaping, adhesive removal, and thermal debonding.

## CONCLUSIONS

- Halogen light induced significantly higher intrapulpal temperature changes than did the LED and PAC.
- The temperature increase was significantly higher at closer distances with all light-curing units.
- All light-curing units produced a higher temperature increase in the pulpal chamber of the mandibular incisor than in the premolar at both distances.
- High-energy output lights produced significantly higher heat changes in the incisor than in the premolar.
- Orthodontic bonding with light-curing units did not exceed the critical 5.5°C value for pulpal health.

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## REFERENCES

1. Gottlieb EL, Nelson AH, Vogels DS. Study of orthodontic diagnosis and treatment procedures. Part 1. Results and trends. *J Clin Orthod.* 1996;12:615–630.
2. Oesterle LJ, Newman SM, Shellhart WC. Comparative bond strength of brackets cured using a pulsed xenon curing light with 2 different light-guide sizes. *Am J Orthod Dentofacial Orthop.* 2002;122:242–250.
3. Oesterle LJ, Newman SM, Shellhart WC. Rapid curing of bonding composite with a xenon plasma arc light. *Am J Orthod Dentofacial Orthop.* 2001;119:610–616.
4. Dunn WJ, Taloumis LJ. Polymerization of orthodontic resin cement with light-emitting diode curing units. *Am J Orthod Dentofacial Orthop.* 2002;122:236–241.
5. Evans LJ, Peters C, Flickinger C, Taloumis L, Dunn W. A comparison of shear bond strengths of orthodontic brackets using various light sources, light guides and cure times. *Am J Orthod Dentofacial Orthop.* 2002;121:510–515.
6. Sfondrini MF, Cacciafesta V, Pistorio A, Sfondrini G. Effects of conventional and high-intensity light-curing on enamel shear bond strength of composite resin and resin-modified glass-ionomer. *Am J Orthod Dentofacial Orthop.* 2001;119:30–35.
7. Cacciafesta V, Sfondrini MF, Scribante A. Plasma arc ver-



- sus halogen light-curing of adhesive-precoated orthodontic brackets: a 12-month clinical study of bond failures. *Am J Orthod Dentofacial Orthop.* 2004;126:194–199.
8. Read MJ. The bonding of orthodontic attachments using a visible light cured adhesive. *Br J Orthod.* 1984;11:16–20.
  9. Zach L, Cohen G. Pulp response to externally applied heat. *Oral Surg Oral Med Oral Pathol.* 1965;19:515–530.
  10. Weerakoon AT, Meyers IA, Symons AL, Walsh LJ. Pulpal heat changes with newly developed resin photopolymerisation systems. *Aust Endod J.* 2002;28:108–111.
  11. 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;110:471–479.
  12. Hansen EK, Asmussen E. Correlation between depth of cure and temperature rise of a light-activated resin. *Scand J Dent Res.* 1993;101:176–179.
  13. Kleverlaan CJ, de Gee AJ. Curing efficiency and heat generation of various resin composites cured with high intensity halogen lights. *Eur J Oral Sci.* 2004;112:84–88.
  14. Cobb DS, Dederich DN, Gardner TV. In vitro temperature change at the dentin/pulpal interface by using conventional visible light versus argon laser. *Lasers Surg Med.* 2000;26:386–397.
  15. Yu D, Powell GL, Higuchi WI, Fox JL. Comparison of three lasers on dental pulp chamber temperature change. *J Clin Laser Med Surg.* 1993;11:119–122.
  16. Powell GL, Anderson JR, Blankenau RJ. Laser and curing light induced in vitro pulpal temperature changes. *J Clin Laser Med Surg.* 1999;17:3–5.
  17. Goodis HE, White JM, Andrews J, Watanabe LG. Measurement of temperature generated by visible-light cure lamps in an in vitro model. *Dent Mater.* 1989;5:230–234.
  18. Hannig M, Bott B. In-vitro pulp chamber temperature rise during composite resin polymerization with various light-curing sources. *Dent Mater.* 1999;15:275–281.
  19. Tarle Z, Meniga A, Knezevic A, Sutalo J, Ristic M, Pichler G. Composite conversion and temperature rise using a conventional, plasma arc and experimental blue LED curing unit. *J Oral Rehabil.* 2002;29:662–667.
  20. Price RB, Ehrnford L, Andreou P, Felix CA. Comparison of quartz-tungsten-halogen, light-emitting diode, and plasma arc curing lights. *J Adhes Dent.* 2003;5:193–207.
  21. Jost-Brinkmann P-G, Stein H, Miethke R-R, Nakata M. Histologic investigation of the human pulp after thermobonding of metal and ceramic brackets. *Am J Orthod Dentofacial Orthop.* 1992;102:410–417.
  22. Shortall AC, Harrington E. Temperature rise during polymerization of light-activated resin composites. *J Oral Rehabil.* 1998;25:908–913.
  23. Usumez A, Ozturk N. Temperature increase during resin cement polymerization under a ceramic restoration: effect of type of curing unit. *Int J Prosthodont.* 2004;17:200–204.
  24. Ozturk B, Ozturk AN, Usumez A, Usumez S, Ozer F. Temperature rise during adhesive and resin composite polymerization with various light curing sources. *Oper Dent.* 2004;29:325–332.
  25. Sheridan JJ, Brawley G, Hastings J. Electrothermal debracketing. Part II. An in vivo study. *Am J Orthod Dentofacial Orthop.* 1986;89:141–145.
  26. Mizrahi E, Cleaton-Jones P, Landy C. Tooth surface and pulp chamber temperatures developed during electrothermal bonding. *Am J Orthod Dentofacial Orthop.* 1996;109:506–514.
  27. Uysal T, Eldeniz AU, Usumez S, Usumez A. Thermal changes in the pulp chamber during different adhesive clean-up procedures. *Angle Orthod.* 2005;75:216–221.