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Effect of Curing Time and Intensity Level on the Temperature Changes of Pulp Chamber During Orthodontic Bonding Using High Power LED Device

Alia Alsafadi[1], Nada Rajeh[1], Rania Haddad[1], Zuheir Marmar[1], Mowaffak Ajaj[1]

Orthodontic department of Dentistry syria-Damascus-alMezza[1]

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ABSTRACT

This study aimed to assess the influence of different curing times and intensity levels on the temperature of pulp chamber during brackets bonding using high power LED. The sample consisted of 108 upper premolars, divided into three main groups according to the curing time and intensity level, the first group (20 seconds,1200 mw/cm²), the second group (5 seconds, 2000 mw/cm²) and the third group (3 seconds, 2500 mw/cm²). The changes of temperature in the pulp chamber and the cooling time were recorded with a thermal imaging camera. There were statistically significant difference between the first and second group and first and third group regarding the changes of temperature, the mean of temperature rise for the first group was 3.58°C Compared to 1.69°C and 1.29°C for the second and third groups respectively. The results of the cooling time showed statistically significant difference between the three considered groups. Reducing the curing time to 3 or 5 seconds with increasing its intensity level up to 2000-2500 mw/cm² is considered to be safer on pulp chamber during and after the curing process.

1. INTRODUCTION

Light-cured composite has been gaining popularity for orthodontic bonding among other adhesives [1], since it has provided the orthodontist with many benefits such as less risk of contamination, easier removal of excess adhesive, and more working time to position the brackets accurately [2]. On the other hand, light-curing units have experienced vast improvements [3], many types have been used for orthodontic bonding, Quartz tungsten halogen (QTH), plasma arc lights (PAC), argon laser, and light emitting diode (LED) [4]. LED lights can provide clinical bonding success with shorter curing times, which can be achieved by increasing the light intensity [5]. And since time is considered to be an important factor during orthodontic bonding procedure for both orthodontists and patients [6], many studies have investigated the consequences of reducing the curing time that is associated with changing its intensity using LED curing lights [7- 10]. Considering that time and intensity are two essential factors that influence each other during this procedure [8]. Furthermore, an increased intra-pulpal temperature has been reported in the literature during composite resin polymerization for different light-curing units [4], [11], [12], giving that most of the studies relied on the safety threshold value of 5.5°C as described by Zack and Cohen, which was considered as a limit value for pulpal damage [13], [14]. Although several studies have evaluated the thermal effects of different curing lights [15], [16] by thermocouple wires to measure the intra-pulpal temperature rise, there were few studies that evaluated the heat rise in the pulp chamber resulted from different curing times and intensity levels when comparing the plasma arc light with LED light [11] in additon to comparing halogen light with LED light [16- 18] by the aid of thermal camera during orthodontic bonding. Thus, the aim of our study was to assess the influence of curing time and intensity on the temperature of the pulp chamber during orthodontic bonding by thermal imaging camera when using high power LED with different parameters.

2. Materials and Methods

The sample size was determined using a statistical power analysis (G*Power Ver 3.1.9.2, Germany). 108 non carious human upper premolars were required to achieve a power of 95% at P=0.05 [19]. The premolars were extracted for orthodontic reasons with no visible buccal defects or restorations, all teeth were processed according to the technical specification ISO/TS 11405:2003. After removing the periodontal tissue remains and calculus, the teeth were kept in formalin 10% for 24 hours, and then stored in distilled water at 4°C. The teeth were split into two halves, buccal and palatal, and the buccal halves were stored in an isotonic solution (Figure 1). Each premolar was etched with 37% phosphoric acid gel for 30 seconds and washed with water for 30 seconds, then dried until the frosty white etched area was observed, A layer of bond (Transbond XT light cure adhesive primer, 3M Unitek, Monrovia, Calif., USA) was applied on the etched enamel and the resin cement (Transbond XT light cure orthodontic Adhesive) was applied on the base of the stainless steel brackets (0.022 Master Series, American Orthodontics). The brackets were immediately set in place and firmly pressed against the buccal surface of the premolars, then a LED Light (Woodpecker I LED Wireless Curing Light) with an output power of 1200 mw/cm² ~2500mw/cm², 420nm-480nm was used to cure the composite. The distance of the light tip to the brackets was kept at the closed distance for all specimens, and the tip of curing device was angulated at 90 degrees to the bracket on each premolar. The sample was divided into three groups according to the curing time and intensity level: group 1: 36 upper premolars with curing time of 20 seconds and a light intensity of 1200 mw/cm², group 2: 36 upper premolars with curing time of 5 seconds of and a light intensity of 2000 mw/cm², group 3: 36 upper premolars with curing time of 3 seconds and intensity of 2500 mw/cm². The measurements were recorded using a thermal imaging camera at the University of XXX. Before taking any thermal measurement, the ambient temperature was set to 26 ± 0.9 °C. The temperature changes during and after bonding were recorded with a FLIR C2 thermal camera (Figure 2).

The camera was located 15 cm away from the sample blocks, and the samples were transferred using plastic forceps to avoid any thermal effect and were then placed on a fixed table to keep away any thermal effect from the curing device head on the measured temperature. Then the recording was started two seconds before the start of curing and the changes of the temperature of the pulp chamber during bonding were measured. The duration for returning from the highest temperature value to the initial degree was recorded for all specimens (cooling time).

Statistical analysis were conducted using (SPSS Inc, 25 Chicago, IL, United States of America), The mean and standard deviation of the temperature changes were calculated for each group, The data distribution was assessed with Kolmogorov-Smirnov test, then the comparison of temperature changes and cooling times between groups were analysed with one-way ANOVA, followed by Tukey HSD test for binary comparison.

3. Results

The greatest temperature rise was observed in the first group (4.60°C) followed by the second group (3.10°C), while the lowest temperature rise was recorded in the third group (2.90°C).

One-way ANOVA test showed statistically significant difference between groups for the changes of the pulp chamber temperature during curing (Table 1). Post hoc Tukey HSD test, showed statistically significant difference between the first and second groups and the first and third groups, while there was no statistically significant difference between the second and third groups (Table 2).

Regarding the cooling time; the first group recorded the longest time required to go back to the initial temperature with 25 seconds followed by the second group with 9 seconds, while the third group showed the shortest cooldown time with 6 seconds only.

One-way ANOVA test revealed statistically significant difference between groups for cooling time (Table 1), when conducting Tukey HSD test, there was statistically significant difference among all three groups (Table 2).

Table 1: one way ANOVA for temperature rise and cooling time								
temperature rise of pulp chamber during curing					**Cooling time of pulp chamber after curing**			
Groups	**Mean(C°)**	**SD**	**F**	**p-value**	**Mean(sec)**	**SD**	**F**	**p-value**
Group1	**3.58**	**0.797**	**102.56**	**0.00**	**39.30**	**9.080**	**98.354**	**0.00**
Group2	**1.69**	**0.760**			**20.66**	**11.744**		
Group3	**1.29**	**0.593**			**10.36**	**3.993**		

Table 2: Tukey HSD for temperature changes and cooling time					
Changes temperature of pulp chamber during curing				**Cooling time of pulp chamber after curing**	
The two comparison groups		**Mean difference**	**p-value**	**Mean difference**	**p-value**
Group 1	**Group 2**	**1.886**	**0.000**	**18.63**	**0.000**
Group 2	**Group 3**	**-0.397**	**0.056**	**10.30**	**0.000**
Group 3	**Group 1**	**-2.283**	**0.000**	**28.94**	**0.000**

4. Discussion

The heat generated by light-curing devices has always been a concern in the clinical practice, especially when using a high power led curing devices as their intensity could exceed 2000 mw/cm² [20]. The dental pulp is a highly vascular tissue rich in cellular and nerve elements, and is considered one of the most sensitive tissues to thermal stimulations, also the blood circulation of the dental pulp plays an important role in the distribution and dissipation of the heat transmitted to the dentin-pulp complex [21]. Although the maximum temperature that can be tolerated by human tissue is still unknown, many researches relied on Zach and Cohen study [14] which considered 5.5°C temperature rise in the pulp chamber as the threshold value before the start of the pulpal damage. Thus, the current study evaluted the intra pulpal temperature rise when using high power LED with three different curing times and intensity levels in addition to the cooling time, since it is essential to protect the adjacent teeth from possible heat related damages during orthodontic bonding, which could provide us with the ideal required time needed before starting to cure the adjacent tooth. On the other hand, there are two main aspects of temperature increment during polymerization of composites with light activation; the first one is the absorbed energy as a result of radiance and heat polymerization process since increased irradiation due to high-energy output lights is consdered a risk factor for pulpal damage [16], [22], [15], and the second aspect is the curing time. However in orthodontic literature the long curing time was the main concern rather than the high-energy level [15], [23].

To our knowledge this is the first study to evalute the effect of different curing times and intensity levels on the temperature of pulp chamber during brackets bonding using high power LED.

Based on the results of this study, the first group showed greater temperature rise in the pulp chamber during curing compared to the two other groups. The mean temperature rise in the first group was 3.58°C compared to 1.69 °C and 1.29°C for the second and the third group respectively.

Thus, the intra pulpal temperature was increased with longer curing time. Furthermore, there was no increase in temperature in the three study groups over the threshold (5.5°C) described by zack and cohen [14], giving that the highest temperature rise recorded in the first group was 4.6°C, which could be due to the amount of energy absorbed by the tooth as a result of light radiation and the polymerization process of the composite. These findings are consistent with a recent study which found that the lowest temperature change was recorded when using high power LED with curing time of 3 seconds [17]. Moreover, on the contrary of restorative studies, the light intensity in orthodontic studies represents a less critical role when compared to the curing time, giving that the energy that is released by the device will penetrate the thickness of the bracket before reaching the adhesive material followed by the the tooth tissue.

The results of this study showed statistically significant difference between the three study groups regarding the cooling time, we found that the longest time taken by the pulp chamber to return to its initial temperature after curing was 58 seconds in the first group (curing time 20 seconds with intensity 1200 mw/cm²), while 45 seconds and 20 seconds were noted for the second and third groups respectively, this could be due to the reaching of the full energy of the curing device, as the light energy is the result of the curing time multiplied by the light intensity [24]. Which is almost in line with a recent study that compared two different light resources, LED light (valo ortho cordless) and plasma arc light, with various power and exposure times and found that the cooling time required was 77.19 second for the longest exposure time with 10 seconds when using high power led (valo) [11]. Our findings would seem to suggest that when curing time increases, cooling time also increases, and around one minute is needed to allow for cooling back to the primary temperature.

The main limitation of our study is that in vitro studies cannot ideally reflect the oral environment such as blood circulation of the pulp chamber and fluid movement in dentin tubules and the role of saliva in cooling the heat transfered from curing devices to the pulp cavity.

5. Conclusions

- Reducing the curing time to 3 or 5 seconds and increasing the intensity level of curing up to 2000-2500 mw/cm² is considered to be safer on pulp chamber during and after the curing process.
- Increasing the curing time during orthodontic bonding increases the cooling time of the pulp chamber.

Abbreviation:

LED: Light Emitting Diode
QTH: Quartz Tungsten Halogen
PAC: Plasma Arc Lights

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