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Thermal Variations in the Pulp Chamber Associated with Composite Insertion Techniques and Light-curing Methods

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Abstract

Aim: The aim of this study was to investigate the effect of different incremental insertion techniques, photoactivation, and restorative phases on thermal variations occurring during the polymerization of Filtek Z250 composite resin.

Methods and Materials: The experiment was conducted using 90 bovine incisor teeth. The teeth were randomly assigned to three groups according to the technique used for photoactivation with a halogen light (continuous, soft-start, or intermittent). The groups were further separated into three subgroups according to method of increment placement (bulk, oblique, or horizontal/vertical) for a total of nine groups (n=10). Restorations were placed in a controlled environment (37ºC and 50±10% RU) and the temperature recorded using a digital thermometer coupled to a Type-K thermocouple inserted in the pulp chamber through the root canal in contact with the dentin. Data were analyzed using an analysis of variance (ANOVA) and the Tukey's test.

Results: Higher temperature values were found for continuous light photoactivation in combination with the placement of horizontal/vertical composite increments and photoactivation of the adhesive using a continuous light exposure.

Conclusion: The light source is the most important factor producing temperature changes during photoactivation of resin composite.

Clinical Significance: Temperature increases in the pulp chamber due to light curing should be considered to avoid harming the delicate pulp tissue when large restorations or inlays/onlays require several consecutive light curing exposures for a complete cure.

Keywords: Temperature variation, composite, photoactivation, insertion techniques

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Introduction

Composite restorations have been recommended for anterior teeth, replacing esthetic silicate cement and acrylic resin fillings.[1] Improvements in composite materials have broadened the clinical use of these restorations to include their use in posterior teeth.

In an attempt to minimize the effect of polymerization contraction promoted by the use of continuous light, other methods have been developed. Among these techniques is the soft-start technique which promotes initial photoactivation with a lower light intensity followed by a final polymerization using a higher intensity.[2,3,4]

An intermittent light method was developed from the adaptation of an electronic circuit to the Optilux 150 device enabling it to emit intermittent light (.5 seconds on and .5 seconds off) at 450mW/cm^2 of power density. This method could be used to minimize the shrinkage due to composite polymerization.[5]

Insertion techniques such as bulk insertion of the composite resin, placement in multiple horizontal increments, and placement of composite resin in oblique and bucco-lingual increments were studied with the same objective to minimize the stress during polymerization of composite resins. Earlier studies found different insertion methods could cause different levels of microleakage in composite restorations.[6,7,8] Composite resin shrinkage due to polymerization has been one of the factors found to be directly responsible for marginal leakage. The layering technique allows a more uniform polymerization and a reduction in total shrinkage.[8]

In an *in vivo* experiment Zach and Cohen[9] submitted the teeth of Rhesus monkeys to different temperature increases and showed irreversible pulp alterations can be generated. Thermal traumas can also be induced during the preparation of the cavities or during the curing reaction of lining materials and restoring materials.[10] It has been suggested the activation by visible light can also contribute to an increase in the internal temperature of the pulp chamber, causing damage to pulp tissue.[11-13]

The objective of this *in vitro* study was to verify the thermal changes occurring in the pulp chamber of bovine teeth, during the polymerization of the Single Bond adhesive system and Filtek Z250 composite resin, related to the composite insertion technique used (bulk, oblique, or horizontal/vertical increments) and three different photoactivation techniques (continuous, soft-start, or intermittent) using a halogen curing light.

Methods and Materials

Ninety bovine incisor crowns were separated from the roots and partially embedded in polyethylene resin, exposing the buccal surface to allow access to the root canal. Cavities were prepared using a standard dental unit with #3098 cylindrical diamond burs (KG Sorensen, Barueri, SP, Brazil) in a high-speed handpiece with an air/water spray coolant. The cavity was prepared in the central portion of the incisal third of the buccal surface 13 mm from the cementoenamel junction with the dimensions being: 2.5 mm in depth, 3 mm in mesial-distal extension, and 3 mm in incisal-cervical extension. The thickness of the remaining dentin of the axial wall was approximately 1 mm (± 0.1 mm), measured earlier with a digital pachymeter in a pilot study.

All preparations were etched with Scotchbond Etching Gel 35% phosphoric acid (3M ESPE Dental Products, St. Paul, MN, USA) for 20 seconds, washed with water for 20 seconds, and the excess moisture removed with absorbent paper. Two layers of the Single Bond adhesive system (3M-ESPE) were used with photoactivation carried out after placement of the second layer, using the Degulux Soft-Start unit (Degussa Dental, Hanau, Germany) according to one of three different photoactivation methods as follows:

1. **Continuous Light:** The tip of the photopolymerizing unit was positioned on the cavity preparation to cure the adhesive layers and later on the polyester strip to cure the composite resin using a light intensity of $700 mW/cm^2$ for 20 seconds.
2. **Soft-start Light:** The tip of the photopolymerizing unit was positioned on a spacer during the first 5 seconds of activation at a distance of 2 cm from the cavity to cure the adhesive using a light intensity of $100 mW/cm^2$. Then the tip was positioned on the cavity for another 15 seconds at a light intensity of $700 mW/cm^2$ (totaling 20 seconds of photoactivation). It was placed on the polyester matrix strip to cure the composite using the same technique following insertion of the restorative material.
3. **Intermittent Light:** The active tip of the light curing unit was positioned on the cavity to cure the adhesive and later on the polyester matrix strip to cure the composite, providing 2 seconds of photoactivation at an intensity of $700 mW/cm^2$ and same time with light off (photoactivation by 20 seconds). In all procedures the light intensity was monitored by a radiometer (Demetron Research Corporation, Danbury, CT, USA).

After the adhesive polymerization, Filtek Z250 composite (Shade A3, 3M-ESPE, St. Paul, MN, USA) was applied using one of three different incremental insertion techniques (Figure 1) and photoactivated using the Degulux Soft-Start light curing unit according to the previously described protocol:

1. A single bulk increment (Figure 1A).
2. Three oblique increments: first composite material was placed at the cervical and axial walls, followed by composite placed in the incisal and axial walls, and the third increment was inserted uniting the two previous increments (Figure 1B).
3. Horizontal/vertical increments: the horizontal increment was placed at the axial wall, the first vertical increment at the cervical wall, and the second one at the incisal wall (Figure 1C).

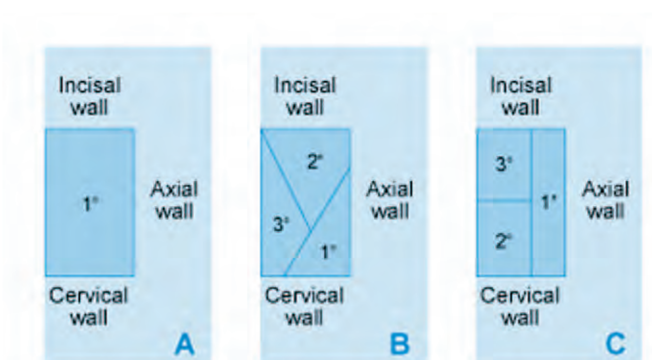

Figure 1. Restoration diagrams established according to the increment type.

Table 1. Groups established.

Groups	Increment	Photoactivation
Group I	Bulk	Continuous
Group II	Bulk	Soft-start
Group III	Bulk	Intermittent
Group IV	Oblique	Continuous
Group V	Oblique	Soft-start
Group VI	Oblique	Intermittent
Group VII	Horizontal/vertical	Continuous
Group VIII	Horizontal/vertical	Soft-start
Group IX	Horizontal/vertical	Intermittent

Nine groups (n=10) were established according to the photoactivation method and the incremental insertion technique used. (Table1).

Cavity preparations were carried out inside an isolation hood used for chemical experiments with the temperature maintained at 37ºC by a heater and at a relative humidity of 50±10% generated by a vaporizer. Both environmental conditions were verified with a hygrometer/thermometer device.

Temperature changes were measured using a Type-K thermocouple connected to a digital thermometer (Iopetherm 46, IOPE, Sao Paulo, SP, Brazil) within an accuracy of 0.1ºC. After the inside temperature of the hood was stabilized at 37ºC, the thermocouple was inserted in the pulp chamber through the root canal[14] in contact with the remaining dentin at the axial wall of the cavity. Then the dental adhesive was applied in the cavity and the temperature remeasured. Temperature was also measured during the photoactivation of the adhesive. Composite was inserted in the cavity according to the increment group assigned, and the temperatures were measured in each stage of the increment technique. The highest temperature reached within the pulp chamber during the entire procedure was recorded as the data point.

One operator performed all cavity preparations, restorations, and temperature measurements. Data were analyzed using an analysis of variance (ANOVA), and the means were compared using a Tukey's test ($\alpha = .05$). The comparisons were among groups, increment method, photoactivation method, restorative phase, and subsequent interactions.

Results

Comparisons of the photoactivation and the increment insertion methods used found the horizontal/vertical increment placement method promoted higher heat using continuous light. The oblique increment placement method promoted higher heat with the soft-start light. There was no difference (p=0.00055) among the increment placement methods using the intermittent light technique (Table 2).

With regard to the restorative phase (adhesive or composite curing) and increment placement method used, adhesive curing produced more heat in the bulk increment placement method. The multiple increments placement methods showed no difference among either adhesive and composite curing steps (Table 3).

With regard to the restorative phase (adhesive or composite curing) and technique used for

Table 2. Mean temperature increase (°C) according to the photoactivation and increment placement methods used regardless of the restorative phase (adhesive or composite curing). (A p=0.00055 value is true only for this table.)

Increment	Photoactivation		
	Continuous	Intermittent	Soft-start
Bulk	37.24 (0.64) a A	37.09 (0.39) a A	37.10 (0.50) a A
Oblique	37.56 (0.61) b A	37.26 (0.36) a B	37.51 (0.65) b A
Horizontal/vertical	37.79 (0.73) c A	37.28 (0.34) a B	37.21 (0.32) a B

Means followed by different small letters in each column and means followed by different capital letters in the each row differ statistically by the Tukey's test. Standard Deviation.= ( )

Table 3. Mean temperature increase (°C) during the restorative phase (adhesive or composite curing) and increment placement method used independent of the technique of photoactivation used. (A p=0.04833 value is true only for this table.)

Restorative Phase	Increment		
	Bulk	Oblique	Horizontal/Vertical
Adhesive application	36.68 (0.41) a A	36.89 (0.19) a A	36.89 (0.08) a A
Adhesive photoactivation	37.54 (0.47) c A	37.73 (0.43) b A	37.72 (0.46) b A
Composite photoactivation	37.20 (0.46) b A	37.71 (0.53) b B	37.67 (0.54) b B

Means followed by different small letters in each column and means followed by different capital letters in the each row differ statistically by the Tukey's test. Standard Deviation.= ( )

photoactivation, there was no influence exhibited by different photoactivation methods on adhesive and composite curing. However, the continuous light photoactivation technique promoted higher heat during adhesive and composite curing when compared with the other photoactivation types (Table 4).

Discussion

The hypothesis was confirmed demonstrating the temperature of the pulp chamber during the adhesive and composite polymerization could be influenced by both composite insertion techniques and different photoactivation methods.

Photoactivation by continuous light resulted in the highest temperature reached in the pulp chamber during curing of the horizontal/vertical increment regardless of the restorative phase (Table 2). In the soft-start technique the highest temperature was generated during the curing of an oblique increment. An earlier study showed increases in light intensity can increase the temperature during the polymerization due to larger radiation energy supplied by the photoactivation unit.[15]

A probable explanation is part of the heat generated by the unit of area is dissipated through the previous polymerized layers, which are farther from the pulp chamber. The earlier polymerized material acts as a dispersive substrate for heat which impedes the heat (produced by polymerization and light intensity) from efficiently reaching the pulp chamber. It is possible part of the heat generated has dissipated through the dentin via the lateral cavity walls and through the virtual cavity wall to the oral environment.

Table 4. Mean temperature increase (°C) during different photoactivation methods employed regardless of the increment placement method used. (A p=0.00002 value is true only for this table.)

Restorative Phases	Photoactivation		
	Continuous	Intermittent	Soft-start
Application of the adhesive	36.79 (0.19) a A	36.88 (0.18) a A	36.80 (0.13) a A
Photoactivation of the adhesive	37.92 (0.53) b A	37.47 (0.32) b B	37.60 (0.39) b B
Photoactivation of the composite	37.88 (0,55) b A	37.27 (0.33) b B	37.43 (0.57) b B

Means followed by different small letters in each column and means followed by different capital letters in the each row differ statistically by the Tukey's test. Standard Deviation.= ( )

During photoactivation there are differences in the levels of light penetration associated with different composites, depending on absorption and reflection of the light in the composite filler particles. Passing through cured composite, light is absorbed and reflected thus losing intensity and reducing the efficiency of the polymerization process.[16,17] In such conditions the heat generated will possibly be lower making it more difficult to reach the pulp chamber.

Heat values registered in the pulp chamber for all increments photoactivated with intermittent light showed no statistical difference. This is probably due to intermittent activation making it easy for the dispersion of the heat when the light was inactivated, resulting in similar heat values for the increment techniques.

When the intermittent light was inactivated, the temperature decreased conditions that were repeated along the cycle. The final temperature achieved in the pulp chamber was due to the small monomer volume polymerized in the end of the process. When the bulk increment was photoactivated, the three photoactivation types generated no significant difference in temperature. In this study the photoactivation type did not influence the temperature demonstrated with the bulk increment. This finding confirms the exothermic process of polymerization as a secondary factor in the increase of temperature.[11]

During the interaction between oblique and horizontal/vertical increments and photoactivation types used, the temperature generated is also a function of the composite thickness. An earlier study showed thinner layers photoactivated for 20 seconds reduced the increase of the temperature.[15] Although warming of the thinner layers is greater than thicker layers,[11] there is no direct relationship with the heat reaching the pulp chamber possibly due to the proximity of the pulp wall, thickness of the dentin, and the process of heat dissipation are interrelated.

Table 3 shows results of the interaction of the increment placement method used and the restorative phase. The heat developed by the bulk increment reaching the pulp chamber was higher during the photoactivation of the adhesive, followed by the composite photoactivation and application of the adhesive. The temperature registered during photoactivation of the adhesive was higher than the one observed during the application of the adhesive and in the activation of the composite. It is possible this result is due to the close proximity of the adhesive to the pulp chamber, the small volume of the adhesive to be polymerized, and probably to a greater dissipation of heat. In such conditions the polymerized adhesive acts as insulation from the heat produced during the composite polymerization which accounts for the lower temperature registered.

The temperature decrease in the pulp chamber during the application of the adhesive was due to the room temperature of the material (± 25ºC) and the pulp chamber at 37ºC (hood temperature). Multiple increments showed no significant difference in the heat reaching the pulp chamber in both adhesive and composite photoactivations. These results confirm the temperatures generated in the adhesive and composite photoactivation were not influenced by the position of the increments in the cavity or by the thickness of the increment layer despite speculation thinner layers can generate more heat.[11]

For a single tooth, it is almost impossible to predict the clinical increase of the temperature that can occur during the restoration with composite. In general, less increase of the temperature will occur when the remaining dentin is thicker and the activation time is smaller.[18] There was no statistically significant difference in the application of the adhesive when the increment type was appraised. Similar results occurred during the adhesive photoactivation. This result shows the influence of the relationship of the proximity of the adhesive to the remaining dentin and heat reaching the pulp chamber, regardless of the increment type and restoring phase.

In the composite photoactivation the lowest heat that reached the pulp chamber was with the bulk increment, while the multiple increments promoted heat with no significant statistical difference. Above a critical composite thickness, it is not possible for adequate polymerization, even with longer exposure to light.[13] Similarly, the heat developed by the single increment that reached the pulp chamber was proportionally lower than the one promoted by multiple increments.

In all photoactivation types (Table 4) there was no statistical difference in the heat reaching the pulp chamber promoted by adhesive and composite photoactivation. This result shows the insulating effect of the polymerized adhesive during composite polymerizing by the different photoactivation types. This *in vitro* study suggests temperature increase is affected by the composite setting and light source. However, the light source is the most important factor producing temperature changes during the composite activation.

Conclusion

Within the limitations of this *in vitro* study, the following conclusions can be made:

1. In the photoactivation and increment interaction the horizontal/vertical increment promoted higher heat with continuous light; the oblique increment promoted higher heat with the soft-start light; and there was no difference among the increment types with the intermittent light.
2. Photoactivation types did not influence the heat produced by the bulk increment; the intermittent light produced smaller heat in the oblique increment; and the continuous light promoted larger heat in the horizontal/vertical increment.
3. In the restorative phase and increment type interaction the adhesive photoactivation produced larger heat in the bulk increment, and for the multiple increments there was no difference among adhesive and composite photoactivations.
4. Increment only influenced the composite photoactivation. For the restorative phase and photoactivation interaction, there was no influence of photoactivation type on the adhesive and composite photoactivation. Continuous light promoted higher heat in the adhesive and composite photoactivation when compared with the other photoactivation types.

Clinical Significance

Temperature increases in the pulp chamber due to light curing should be considered to avoid harming the delicate pulp tissue when large restorations or inlays/onlays require several consecutive light curing exposures for a complete cure.

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