Influence of Light Intensity on Temperature Rise During Polymerization of a Composite Resin Sample (Part II)

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Summary

One of the most important side effects of composite material setting using halogen devices besides polymerization shrinkage is temperature rise. The temperature rise is in direct relation with the strength of polymerization light intensity and as intensity grows so does the temperature. Since many polymerization devices exist on the market today capable of producing several different polymerization modes with different distribution of light intensity within the polymerization interval as well as different strength, the purpose of this study was to examine the influence of different polymerization programs (modes) on temperature rise in a sample of composite material. In the experiment Tetric Ceram (Vivadent, Schaan, Liechtenstein) and Filtek Z 250 (3M/ESPE Dental Products, St. Paul, MN) composite materials were used. Composite material samples were polymerized by Elipar Trilight halogen device (3M/ESPE, Seefeld, Germany) with three polymerization modes of various intensities (middle (ET), exponential (ETE) and standard (ETS)). Highest temperature rise was noted after 40 seconds at highest intensity mode (standard mode), while lowest temperature rise was noted at exponential mode after 10 seconds and at medium intensity mode after 40 seconds.

Key words: *polymerization devices, composite materials, polymerization, temperature rise.*

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Introduction

When using composite materials and adhesives during restorative procedure danger exists from short term reactions to permanent damage to the pulp. Most often mentioned factors that cause pulp reaction are local anesthesia, mechanical cavity shaping, dentin etching, and incomplete hybrid layer creation with insufficient sealing of the tubules, insufficient polymerization with consequential release of unreacted residual monomer, polymerization shrinkage, resulting in microlekeage and bacterial penetration and temperature rise during process of polymerization of composite materials.

Today, there are a large number of halogen devices available on the market for polymerization

of composite materials with intensity greater than 1000 mW/cm^2, and a tendency for faster and more efficient polymerization of the composite filling. Greater outgoing light intensity as a result of higher energy radiating from the polymerization device causes greater rise in temperature (1, 2).

Temperature rises with a rise in light intensity and time of exposure. Masutani et al (3) showed that speed of exothermic reaction of light cured composite materials grows with increased intensity of the emitted light. They also concluded that the material itself has greater influence on the temperature rise during polymerization than the light source. On the other hand Strang (4) in his work showed that light source has greater influence on temperature rise than the reaction in the material itself.

Temperature rise in the pulp tissue is not only caused by intensity and exposure to the blue light, but also by the color of the composite material, layer thickness and porosity of the composite material (5, 6). Temperature rise causes coagulation of the protoplasm, expansion of the liquid in the pulp and dentin tubules, increases flow of liquids from dentin tubules, while expansion of the liquid inside the pulp tissue can damage the blood vessels and result with consequential tissue necrosis (7).

Zach and Cohen (8) determined in 1965 that rise in temperature of 5.5ºC causes irreversible pulp damage in 15% of cases, while temperature rise of 11.2ºC causes necrosis in 60% of the cases.

The purpose of the study was to show the influence of three curing modes with different light intensities on the temperature rise of two composite materials during photopolymerization.

Materials and methods

For this experiment composite materials Tetric Ceram (TC) (color A1) (number B49177) and Filtek Z 250 (F) (color A1) (number 20000222) were used. Composite material samples were polymerized with a Elipar Trilight halogen polymerization device with three polymerization modes of different intensities:

1. "Medium mode" (ETM)
2. "Exponential mode" (ETE)
3. "Standard mode" (ETS)

Wavelengths of the emitted light encompass wavelength area from 400 to 515 nm.

ETM mode emits uniform intensity light of 450 mW/cm^2, and represents a control group. Polymerization using ETE mode starts with intensity of 100 mW/cm^2 and gradually rises during 15 seconds to the intensity of 800 mW/cm^2, and holds that value until passing of the 40th second. ETS mode emits uniform light intensity of 800 mW/cm^2.

Samples of composite material for temperature measuring were prepared in plastic moulds 4x4x4 mm size. Temperature was measured using Metex M-3859 D multimeter (Primasens, Winzeln, Germany) with the tip of the temperature probe immersed in the unpolymerized composite material sample to 1 mm depth. Mould for the samples was left open from above and on one side, so the temperature probe, calibrated to 1mm, was immersed sideways and light source placed on the upper surface. As a result direct heating of the temperature probe by the polymerization device was avoided (9). TC samples were polymerized for 40 seconds and F composite material for 20 seconds. After the completion of the polymerization time (recommended by the manufacturer for each material), the temperature probe was left immersed in the sample for the following 40 seconds to observe changes in the material after the end of polymerization.

Metex M-3850 D multimeter was connected with a personal computer, and separate graphic representation of temperature rise was made for each sample for every second of the polymerization.

A total of 60 samples were divided into 30 for TC and 30 for F composite material. The groups of 30 samples of each material was divided into three parts: 10 samples for polymerization with ETM mode, 10 samples with ETE and 10 samples with ETS mode.

Results obtained were statistically analyzed using descriptive statistical methods, ANOVA for difference in temperature considering light source and t-test for independent variables to determine whether there is a difference in temperature between the composite materials used.

For each material and every polymerization mode six consecutive measurements were made.

Results

Results of the temperature measurements are shown in Tables 1-3. Figures 1 and 2 represent temperature rise for every second of polymerization.

Differences in temperature were observed in relation to the light source individually for materials F and TC (analysis of variance) (Table 1 and 2).

When F composite material was used no temperature difference was found in relation to the polymerization mode after 10 seconds ($p>0.05$). At the end of polymerization (after 20 seconds), difference was found between all three light sources ($p<0,05$). Greatest difference was noticed when ETS polymerization mode was used (Table 1)

In the case of TC composite material, differences in temperature were found after 10, 20 and 40 seconds (end of polymerization) ($p<0,05$) for all three light sources. After 10 and 20 seconds the greatest temperature rise was observed in ETS polymerization mode and least in ETE, while after 40 seconds the greatest again in ETS and smallest in ETM (Table 2).

This study also determined differences in temperature in relation to the material (F:TC) using t-test for independent variables at the 10th second and at the end of polymerization (at the 40th second for TC and 20th second for F) (Table 3).

ETM polymerization mode exhibited difference in temperature between the two materials used in the study at the 10th second ($p<0,05$), but there was no difference at the end of polymerization ($p>0.05$). TC had higher temperature for the entire period of illumination.

ETE polymerization mode exhibited difference in temperature ($p<0.05$) between the two materials both at the 10th second and at the end of polymerization. F showed higher temperature at the 10th second and TC at the end of polymerization.

ETS polymerization mode exhibited difference in temperature between the two materials at the 10th second ($p<0.05$) while there was no difference in temperature at the end of polymerization ($p>0.05$). TC exhibited higher temperature for the entire illumination period.

Discussion

One of the negative side effects of the composite material polymerization is unavoidable temperature rise caused by the heat of the chemical reaction that takes place in the material itself on one side, and heat created by the emitted light of specific wavelength on the other side. Since halogen devices for polymerization of composite materials emit a wide spectra of wavelengths filters are incorporated inside, which separate unnecessary wavelength responsible for producing unnecessary heat and therefore temperature rise. Light source energy and energy created by the chemical reaction inside the material can be harmful to the pulp tissue, therefore unnecessary wavelengths above 500 nm should be eliminated (10, 11). Besides regular control of the outgoing intensity by radiometer it is also necessary to regularly check filters of the bulbs to avoid greater harmful warming of the composite material because of the inability of halogen bulb cooling, or ability to reduce the heat produced at higher wavelengths (higher than 500 nm). Inadequate filters cause temperature rise of 18.5-21.2ºC in comparison to adequate filters where that rise stays in the interval between 12.1 to 13.1ºC when illuminated by halogen device (12, 13).

Results obtained in the experiment show that light source intensity influences temperature rise during setting of the composite material. ETE mode, because of lower initial intensity produces lower temperature rise (TC 4.80±0.91; F 7.0±0.66 after 10 seconds) than ETM mode (TC 8.7±0.82; F 7.8±0.91) and ETS mode (TC 12.2±0.91; F 7.6±0.84). Temperature rise during setting is also influenced by the composite material composition. Both TC and F are structurally finely grinded hybrid composite materials with particle size from 0.04-3 μm for TC and 0.01-3.5 μm for F. Inorganic filler ratio for TC equals 50% volume, and for F 60%. Difference is in the composition of the organic matrix; while TC has BisGMA, UDMA and TEGDMA, F instead of TEGDMA has Bis EMA. BisGMA is basic component of the organic matrix, but since it is very viscous dilutors are added to decrease viscosity and ensure better filling with the inorganic phase. Viscosity of the organic matrix influences proportionally the speed of setting of the composite material.

BisEMA, incorporated in F composite material is more viscous and enables faster polymerization of the material. This property explains approximately the same temperature rise for TC polymerized for 40 seconds and F for 20, with light sources of continuous intensity, in this case ETM mode (TC 12.2±0.91; F 7.6±0.84) and ETS mode (TC 14.9±0.73; F 14.7± 0.82) (Table 1, Figures 1 and 2). However, at lower initial intensity (ETE mode), there is a difference in temperature rise for the first 10-15 seconds. Double temperature rise is visible for F composite material, as expected considering BisEMA ratio as well as setting time for each material as recommended by the manufacturer.

Studies by Pilo et al (12) confirm our findings, and similar results were also obtained by Sakaguchi (14). According to the following authors rapid temperature rise appears in the first 20 seconds. This property is represented in Figures 1 and 2 as well as a plateau reached around the 50th second. Prolonging the polymerization time for more than 50 seconds will not cause temperature rise over 14.4 C, but it will increase the total energy applied to the tooth, or in other words total warming of the tooth.

Highest temperature rise, according to the some authors, occurs during the polymerization of the first layer, so in deep cavities polymerization mode of choice would be the one with lower initial intensity to induce lower temperature rise (9,15). However, this poses the question of sufficient setting of the first layer at the deepest part of the cavity because with lower intensity, the strength of light intensity decreases with the increase in distance of the light source from the composite layer on the bottom of the cavity.

Since depth of polymerization cannot be compensated by prolonging the time of exposure, the recommendation is to place the composite material in several layers rather than in one layer with prolonged exposure time, that could cause significant rise of temperature inside the pulp tissue (16,17). Because manufacturers do not always specify exact ratio of components, it is difficult to determine the behavior of each composite material during the process of setting. Therefore, it is up to the practitioner to choose the adequate light source and by proper technique of composite application (layering technique) reduce as much as possible the harmful influence of temperature on the vital pulp tissue. However, the question remains whether the pulp is more often damaged by the temperature rise during polymerization or because of material shrinkage and as a consequence appearance of microcracks with microlekeage and infiltration of bacteria or, because of the influence of non-reacted components of the composite material after completion of the polymerization process.

Conclusion

Temperature rise in composite resin sample is influenced by light intensity of the curing unit used. The highest temperature rise was recorded during illumination with highest intensity mode (ETS), while lowest temperature rise was recorded in the case of illumination with ETE mode after 10 seconds and ETM mode after 40 second illumination of TC and ETE mode after 20 second illumination of F composite material.