Effect of bench time polymerization on depth of cure of dental composite resin

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Abstract. The aim of this research was to investigate the effect of bench time before light cured polymerization on the depth of cure of dental composite resin. Nanofiller composite resin (Filtek Z350 XT,3M, ESPE,China) was used in this study. Sixty samples of nanofiller composite resin were made and divided into control and test groups with bench time for 0, 15, 30, 45, and 60 min. For the test group, composite resins were stored in refrigerator with 4°C temperatures. Meanwhile, for the control groups, the composite resin was stored at room temperature. The samples were prepared using metal mould with size diameter of 6 mm and 4 mm in thickness. Samples were cured for 20 s by using visible blue light curing unit. Part of samples that unpolymerized were removed by using a plastic spatula. The remaining parts of samples were measured by digital caliper and noted as depth of cure (mm). Data were analyzed to one-way ANOVA and LSD tests (p≤0.05). Results showed there was no significance differences between test groups (p=0.5). A 60 minutes bench time group showed the highest depth of cure value among test group, and it was almost similar with control group value. It can be concluded that longer bench time can increase the depth of cure of composite resin.

1. Introduction

A common practice done by dentists is storing the composite resin in a refrigerator at 4°C if it is not used for a long time. This is also suggested by the manufacturer of composite resin and it aims to maintain the stability and prolonged the shelf life of the composite resin. But it did not explain any further about when is the right time to use after removing it from the refrigerator. Dentists might usually use it wait for a while or immediately after it is removed from the refrigerator.

There are several parameters that affect the polymerization of the composite resin, which are composition, color and translucency, light devices characteristics, irradiation distance, exposure time and temperature of the composite resin [1]. Providing temperature treatment on the composite resin before curing can improve its properties. Some studies prove that the temperature of composite resin before curing affects its properties. The temperature can affect the degree of polymerization of the composite resin. Awliya (2007) found that higher temperature increases the polymerization of composite resin [2] Muniz et al., (2013) found that heating the composite resin before curing can increase the hardness [3].
Composite resin polymerization is related to the depth of cure. The depth of cure of composite resin depends on the light penetration into the composite resin. Depth of cure is related to material thickness, wavelength of light, irradiation distance, and spread of light. The intensity of the beam on the surface of the material is very important in improving the polymerization of composite resin [1,4]. Munoz (2008) found that preheating resin composites with a composite warmer increases the monomer conversion rate and increases the depth of cure and hardness of the tested composites [5].

From the explanation above, it can be seen that temperature can affect the polymerization of the composite resin. With the suggestion to store the composite resin in a refrigerator at 4°C, it may affect the depth of cure. Previous study explained that preheating composite resin by using a composite warmer can increase depth of cure and hardness of composite resin. But not yet study before, that explained about allow the dental composite resin at room temperature for several minutes after storage in refrigerator to increase the depth of cure. The aim of this study is to investigate the effect of bench time before light cured polymerization on the depth of cure of dental composite resin.

2. Materials and Methods

2.1 Sample Preparation

Sixty samples were prepared using nano filler composite resin (Filtek Z 350XT, 3MESPE, China) with the measurements of 6.0 mm in diameter and 4.00 in height. Samples were divided into control group and test group. Materials in control group were stored at 24°C and test group were stored at 4°C for 10 days. For the test groups, samples were divided based on bench time of 0, 15, 30, 45 and 60 min at 24°C after removed from refrigerator. Nano filler composite resin was filled into steel molds, which were previously coated with silicon oil. The mould was placed on a strip of a transparent film covering a filter paper and was filled with the test material until the mould is slightly overfilled. Then a second strip of the transparent film was placed on top. The mould and strip of the transparent film were pressed between glass slides to exude the excess material. The microscope slide was removed and gently placed at the exit window of the external energy source against the strip of film. The material was irradiated for 20 s by using light curing unit. The sample was removed from the mould after completion of light exposure.

2.2 Evaluation of Depth of Cure

After the samples were cured, the uncured material was gently removed by using a plastic spatula. The height of the cured samples was measured by using a digital caliper to an accuracy of ± 0.1 mm. This value was recorded as the depth of cure of samples.
2.3 Statistical Analysis

Data were analyzed using one way ANOVA and Least Significance Data test for finding significant differences between groups (p≤0.05).

3. Results and Discussions

The results of depth of cure are summarized in Table 1. The highest value of the depth of cure is control group (3.90±0.07 mm). The depth of cure of composite resin with a bench time of 60 min (3.897±0.09 mm) almost similar with control group. Whereas the lower depth of cure was composite resin with a bench time of 0 mm (3.8254±0.17mm) among the test group. One way ANOVA revealed a non significant differences among test group (p=0.504).

| Group                  | Depth of cure (mm) | p value |
|------------------------|--------------------|---------|
| Control                | 3.9 ± 0.07         |         |
| Bench time of 0 min    | 3.8 ± 0.17         |         |
| Bench time of 15 min   | 3.8 ± 0.10         |         |
| Bench time of 30 min   | 3.85 ± 0.10        | 0.504   |
| Bench time of 45 min   | 3.9 ± 0.07         |         |
| Bench time of 60 min   | 3.9 ± 0.09         |         |

Composite resins are not stable at room temperature and therefore require refrigerated storage below 8°C [12]. Some manufacturers recommended to storing composite resin under refrigeration to make it more durable. If such materials are used at this temperature, one could suppose that retardation of the reaction speed could occur, resulting in a cure beyond the ideal. This is because the refrigeration can increase the viscosity of the material, lowering movement of monomer and altering polymerized composite resin. So it can be presumed that the materials used directly in the teeth after patching procedures when stored in the refrigerator will have an inadequate polymerization [10]. The results in this study showed that samples with the bench time of 60 min after removal from the refrigerator has the greatest depth of cure. The depth of cure value that obtained from samples with a bench time of 60 minutes was also almost similar to the value of the composite resin that was stored at room temperature. While the samples with a bench time of 0 min. showed the lower value of depth of cure. The data of this study showed the longer the bench time will increase depth of cure of composite resin. Therefore, the lower the temperature during the time of polymerization of the composite resin, the lower the energy
molecule initiator to initiate the polymerization process. This will certainly decrease the depth of cure of composite resin as obtained in this study. However, there are no significant differences statistically between test groups. Resin composites in the control group had a depth of cured almost similar to composite resin with a bench time of 60 min. This is probably due to the temperature of the composite resin with a bench time of 60 min is almost close to room temperature.

Temperature plays an important role in the process of composite resin polymerization because it is related to the viscosity of composite resin. High temperature will decrease the viscosity and low temperature may increase the viscosity of composite resin. Viscosity is associated with the speed of molecules movement during polymerization. High temperature will increase the movement of monomer and free radicals. Whereas low temperature will lower the movement speed of monomer molecules to react during polymerization [9,10].

Adequate polymerization of composite resin depends on depth of cure. The depth of cure is the distance from the surface to the base of composite resins that has undergone curing. The depth of cure depends on the light penetration that is related to the thickness of the material, the wavelength, irradiation, and the spread of light. The intensity of the beam on the surface of the material is very important in improving the polymerization of composite resin [1,11]. Several factors affect the depth of cure of composite materials with shade and translucency being the most significant ones [12].

Adequate polymerization is an important factor in obtaining optimal physical properties and good clinical performance of composite resin restorative materials [6]. Some problems related to inadequate polymerization are decrease in physical properties, solubility in the oral environment, and increase in occurrence of micro leakage that causes recurrent caries and irritation of the pulp tissue [7]. Three basic components required for adequate polymerization are radiant intensity, correct wavelength of visible blue light and curing time. Other factors include type of composite resin, color and translucency, temperature of composite resin, material thickness, distance of light exposure and exposure time [8].

Temperatures which was related to the viscosity of the composite resin, that determines the speed of movement of the composite resin molecules during polymerization. Monomer require the movement to be able to convert forming polymer. But since storage at lower temperature will increase the viscosity of the resin composite and decrease the mobility of monomers, it would interfere with the polymerization. So it takes time to increase the temperature of the new composite resin removed from the refrigerator before it is polymerized [10].
The heat effect on the monomer that may contribute to enhance the degree of curing and mixing so thus mechanical strength can be improved. Heating reduces the resin viscosity with the activation energy ranging from 21.9-27.6 kJ/mol [13].

Some factors have been proposed for the increased conversion of preheated composites. An elevated composite temperature leads to an increase in molecular mobility. Therefore, the propagation stage takes longer time without becoming diffusion controlled. Furthermore, temperature rise below the glass transition improves the mobility of polymer chain, postponing the reaction diffusion-controlled termination. By improving the monomer conversion the glass transition temperature will be increased inducing a greater amount of conversion at higher polymerization temperatures [14].

Several previous studies suggest that the use of composite resins at higher temperatures will trigger greater monomer conversion. An increase in temperature causes an increase in the composite resin molecular mobility. Therefore, the propagation phase will last longer without their diffusion controlled. Furthermore, the increase in temperature below the glass transition will increase the mobility of the polymer chain, delaying the termination of diffusion controlled reactions. By increasing the glass transition temperature of the monomer conversion will increase the number of conversions at high polymerization temperature [14]. Additionally, because the composite resin temperature increase may accelerate the conversion of the monomers, both the preheating and the light curing unit may induce a fast increase in the material toughness, leading to greater shrinkage stress [15]. It is known that the curing process is not only break chemical chain reaction, where the double carbon bond to break down into molecules that bind to each other to form a polymer chain. It is also known that the higher temperature will shorten the time of induction, in which the initiator molecules become more energized or activated and initiate the transfer of energy to the monomer molecule [14].

4. Conclusion
It can be concluded that that longer bench time at room temperature after storage the composite resin in refrigerator can increase the depth of cure of composite resin. A bench time is necessary if dental composite resin was stored under refrigerator before use as restorative material to obtain optimum depth of cure.
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