10.5005/jp-journals-10029-1180

RESEARCH ARTICLE

Protective Effects of Base Cements against Intrapulpal Temperature Rise during Curing of Composite Resins: An *In Vitro* Study by Pulpal Blood Microcirculation Model

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ABSTRACT

Aim: Measuring the temperature increases in the pulp chamber during polymerization of resin composites when various base cements were applied on the cavity floor, by using a pulp microcirculation simulation model with physiologic temperature.

Materials and methods: Study performed with four groups of 10 experiments each. Class V cavity with 3 x 4 x 2 mm^3 size was prepared on human mandibular premolar tooth with 1 mm pulpal wall thickness. Pulpal microcirculation and temperature regulation of the tooth within physiological limits performed with an experimental mechanism. In groups 1–3, polycarboxylate cement (PC), conventional glass ionomer cement (GIC) and resin-modified glass ionomer cement (RMGIC) were applied as base cements, respectively. No base material was used in group 4. Restorations were completed with the same composite resin and cured for equal time (20 s) using Demi™ Plus Dental-Curing-LED-Light (1200 mW/cm^2). Temperature increases (Δt) in the pulp during curing of resins were recorded and statistically analyzed with Mann–Whitney U and Kruskal–Wallis test.

Results: The highest Δt values were measured in group 4 (5.76 ± 0.25), group 3 (5.44 ± 0.19), group 1 (4.95 ± 0.32) and group 2 (4.86 ± 0.4), respectively. There were statistically significant differences between group 2 and group 4, and groups 1 and group 4 in Δt values ($p = 0.0001$).

Conclusion: Applying base cements is significantly effective in reducing the temperature increases generated in the pulp tissue. PC and GIC have been found to be more effective than RMGIC in preventing the pulp tissue against thermal stimuli.

Clinical significance: This research is important to provide to clinicians critical information about the temperature increases which may occur in the pulp during curing of composite resins and precautions to be taken.

Keywords: Base cements, Intrapulpal temperature increase, In vitro study, Light curing of composite resins, Pulp microcirculation, Thermal insulating.

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How to cite this article: Ertugrul IF, Yazkan B, Ertugrul CÇ. Protective Effects of Base Cements against Intrapulpal Temperature Rise during Curing of Composite Resins: An *In Vitro* Study by Pulpal Blood Microcirculation Model. Int J Experiment Dent Sci 2018;7(2):85-90.

Source of support: Nil

Conflict of interest: None

INTRODUCTION

Maintaining the vital pulp tissue in restorative treatments is one of the most important issues to be considered. The vitality of pulp tissue can be affected by many factors such as thermal, physical, chemical in dental procedures.[1,2]

Polymerization of resin composites cause a temperature rise in the pulp chamber because of both the exothermic reaction and the absorbed energy during light-induced polymerization.[3-5] The temperature rise in the pulp chamber varies accordingly depth of restoration, application of base cements, transmission properties of the composite resins, the output power of light curing unit used and duration and distance of irradiation.[6-8]

Essentially, dentin has a low thermal conductivity; however the risk of pulp tissue damage is greater in deep cavities as the tubular surface area is increased.[9,10] Temperature increases up to 20°C or more have been measured during curing of the composite resins.[3-5] Due to a temperature increase during polymerization, reversible or irreversible changes in the pulp tissue and even necrosis can occur.[2,11] Features such as fluid motion in the dentin tubules, pulp microcirculation, and blood flow provide heat regulation of the pulp against the temperature increases.[10,12] Pulpal microcirculation is one of the most important factors in the regulation of pulp temperature and it has been reported that higher intrapulpal temperature changes are obtained when pulpal microcirculation is not simulated in the experimental studies.[12,13]

For many years, base cements have been successfully applied in deep cavities to prevent the pulp tissue from thermal and toxic effects of the composite resin polymerization process. For this purpose, materials such as polycarboxylate cements, conventional glass ionomer cements, and resin-modified glass ionomer cements are frequently used in restorative dentistry.

In this *in vitro* study, it was aimed to measure the temperature increase in pulp chamber during polymerization of resin composites when various base cements were applied on cavity floor, by using a pulp microcirculation simulation model and to investigate the differences between the thermal insulating properties of applied cement materials. The null hypotheses of this study were as (1) there would be a higher temperature increase in the pulp chamber when there is no base cement applied on the cavity floor, (2) the different base cements would have no different preventive effects against intrapulpal temperature increaseduring curing of composite resin.

MATERIALS AND METHODS

This study was approved by the Human Ethical Committee of the Medicine Faculty with the reference number 60116787-020/14058.

Preparation of the Specimens

The study was performed with four groups of 10 experiments each. Extracted human mandibular premolar teeth were collected and stored in 0.1% thymol solution until the day the measurements are made. In order to prevent morphological and structural differences which may occur due to the use of multiple teeth, the study was carried out on one sample tooth model.

Class V cavity with 3 x 4 x 2 mm^3 size was prepared on a human mandibular premolar tooth with a pulpal wall thickness of 1 mm. Dentin thickness was confirmed with radiographically. The roots were separated approximately 1 mm below the cement-enamel junction perpendicular to the long axis. The remnant pulpal tissues were removed with an excavator, and the pulp chamber was irrigated with distilled water and dried with air. To insert thermocouple, the entrance to the pulp chamber is prepared as needed (Fig. 1).

Study Design

A K-type thermocouple (TT-K-30-SLE; Omega Engineering Inc, Stanford, CT, USA) was located into the pulp chamber in contact with the axial wall with thermal grease (ZM-STG2; Zalman Tech Co Ltd, Dongan-gu, South Korea). The space around the thermocouple wire was filled with light-curing glass ionomer cement (Ionoseal; Voco, Cuxhaven, Germany) to avoid leakage from the system (Fig. 1). The thermocouple cable is attached to adata logger (DT-3891G; CEM, Shenzhen, PRC) which was connected to a computer for monitoring the temperature changes (Δt).

Pulpal blood microcirculation and temperature regulation of the teeth within physiological limits (37°C ±1°C) were performed with an experimental mechanism made for this study (Fig. 1). Two 25-gauge needles (8696569000777; Hayat Medical Co., Istanbul, Turkey) were placed to provide intrachamber microcirculation through the hole of the temperature-controlled aluminum base plate (TCAP) and used as distilled water inflow and outflow way. The teeth were fixed on the TCAP with light-curing glass ionomer cement (Ionoseal; Voco, Cuxhaven, Germany) in such a way that the needles overlapped with the pulp chamber. The distilled water was flowed through the pulp chamber with 0.0125 mL/min flow rate by using an infusion pump set (IP12A; Biocare, Shenzhen, PRC) (Fig. 1). To obtain physiologic temperature in the pulp chamber, a spiral shape 4 mm diameter copper tube was attached under the aluminum base and connected to a water bath with a standard infusion set. Hot water was flow from inside the copper tube to regulate the physiologic temperature of the TCAP (Fig. 2).

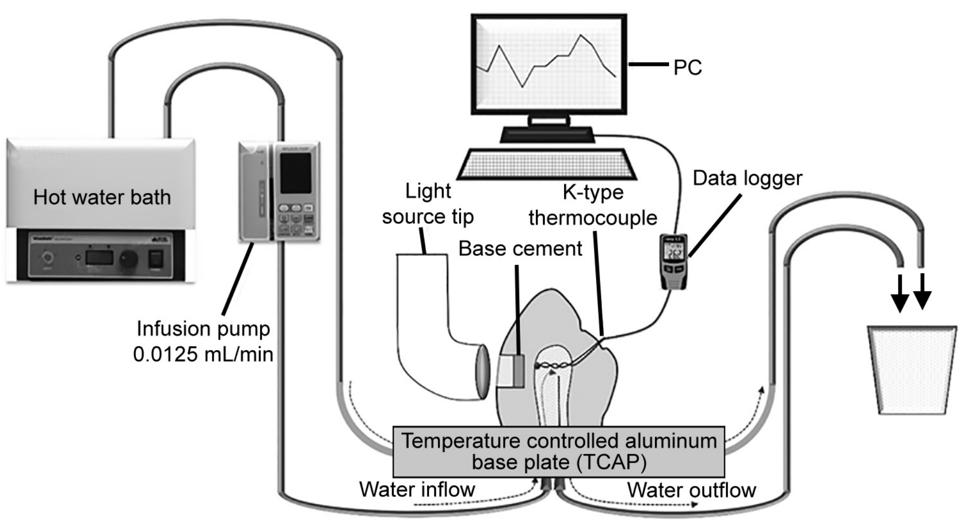

Fig. 1: Schematic drawing of the mandibular premolar tooth and class V cavity with experimental microcirculation apparatus

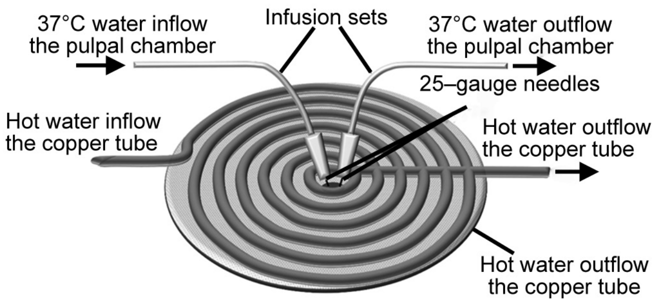

Fig. 2: Bottom view of the temperature-controlled aluminum base plate (TCAP), which is part of the experimental apparatus to regulate the tooth physiological temperature

Table 1: Base cements and restorative materials used in the study

Groups	*Base cement material*	*Composite resin material*	*Light curing unit*
1	Polycarboxylate cement	Filtek Ultimate, 3M/ESPE	Demi™ Plus Dental Curing LED Light, 1200 mW/cm^2,Kerr Dental
2	Conventional glass ionomer cement		
3	Resin-modified glass ionomer cement		
4	No cement		

In the groups 1–3, polycarboxylate cement (PC) (Spofa Dental, Jičín, Czech Republic.), conventional glass ionomer cement (GIC) (Advanced Healthcare Ltd. (AHL), Tonbridge, Kent, UK.) and resin-modified glass ionomer cement (RMGIC) (Ionoseal; Voco, Cuxhaven, Germany) were applied respectively, as base cements with 1 mm thickness on cavity floor (Table 1). Following the application of the base cement, no bonding agent was used to remove composite resin material from the cavity easily. Restorations were completed withthe same conventional composite resin material (Filtek Ultimate, 3M/ESPE, MN, USA) in all groups and werecuredfor equal time (20s) using Demi™ Plus Dental Curing LED Light (1200 mW/cm^2, Kerr Dental, Orange/CA, USA). In group 4 (control group), no base material was used and the cavity wasfilled directly with the same composite resin. Intrapulpal temperature changes were evaluated while implementing curing unit to the buccal direction of the class V cavities from 1 mm distance. The measurements were made at 37°C and only during the photopolymerization process of the composite resins. The differences between initial and maximum temperatures (Δt) in the pulp chamber axial wall during curing of composite resins were recorded, and the Δt values obtained in all groups were compared.

Statistical Analysis

The statistical analyses were performed by using the IBM statistical package for social sciences software (SPSS version 23.0; SPSS Inc., Chicago, IL, USA). The Shapiro–Wilk omnibus normality test, Kruskal–Wallis test followed by Mann–Whitney U multiple comparisons test were used to analyze the differences of temperature changes between the groups at a significance level of $p < 0.05$.

Table 2: The mean and median values of the temperature changes (Δt) measured in each group

Groups	*Base cement*	*Temperature change (Δt)* Mean±SD	*Median (min–max)*
1	Polycarboxylate cement (PC)	4.95 ± 0.32	4.95^a (4.3–5.4)
2	Conventionel glass ionomer cement (GIC)	4.86 ± 0.4	4.85a (4.2–5.5)
3	Resin-modified glass ionomer cement (RMGIC)	5.44 ± 0.19	5.5^{ab} (5.1–5.7)
4	No cement	5.76 ± 0.25	5.85b (5.2–6)

SD: Standart deviation
The values indicated by a and b are statistically significantly different from each other ($p = 0.0001$). ^{ab} is not significantly different from the values indicated by ^{a} and ^{b} ($p > 0.05$)

RESULTS

The mean and median values of calculated temperature changes in the groups are presented in Table 2. The highest Δt values were measured in group 4 in which no base cement was applied, as expected. The highest Δt values after the control group (group 4) were measured in the resin-modified glass ionomer cement applied specimens (group 3), while the conventional glass ionomer cement applied group (group 2) had the lowest Δt values (Table 2).

There were statistically significant differences between group 2 and group 4, and group 1 and group 4 in Δt values ($p = 0.0001$). Temperature increases measured in group 3 are lower than in group 4, but differences are not statistically significant ($p > 0.05$). Differences between mean Δ*t* values of the PC applied group (group 1), GIC applied group (group 2) and RMGIC applied group (group 3) were not statistically significant ($p > 0.05$).

DISCUSSION

In recent years the increased power of dental light curing units may also cause harmful temperature increases in pulp tissue. In the past, it was believed that the pulp tissue could reverse from the temperature changes caused by conventional light curing devices; however, Zach and Cohen[2] shown that temperature increase of only 5.5°C in healthy pulp tissue resulted in 15% of the teeth in rhesus monkeys developed necrosis. It has been concluded in researches carried out on this subject that irreversible changes in the pulp started at temperatures of 42–42.5°C.[2,14]

Although many different light curing devices have been developed recently in dentistry, due to the advantages of light emitting diode (LED) light curing units (LCU) such as less heat generation, resistance to overheating and longer lifetime, these devices have been more widely used in restorative dentistry.[15] These advantages led to the preference of a LED LCU in the current study, as well.

The decisive factor for temperature increase during light-activated polymerization of composite resins is firstly the energy absorbed during irradiation and secondly the exothermic reaction of the process.[4] On the other hand, many factors may affect the behavior of dentine-pulp complex against thermal stimuli including the intensity and duration of the stimulus, the fluid motion in dentin tubules, the pulp microcirculation and the pulpal blood flow changes due to stimulation of the pulpal nervous system.[16]

The role of pulp microcirculation as a cooling agent in the thermal regulation of the dentin-pulp complex was evaluated in a few studies. In lots of *in vitro* studies, the specimens were placed in a water tank containing standing water at 37°C.[17,18] In this study, in order to simulate the microcirculation of the pulp chamber, a microcirculation mechanism was created. This mechanism allowed water to circulate within the pulp chamber at a defined flow rate and pressure to simulate *in vivo* conditions. When the coronal pulp chamber volume of the mandibular premolar teeth was accepted approximately as 0.025 mL, the serum infusion pump was set to 0.0125 mL/min to stimulate microcirculation in the pulp chamber.[19] In our pilot study, it was determined that the physiological temperature in the pulp chamber which is tried to be adjusted only by microcirculation, was very unstable. Therefore, in the current study in order to obtain physiologic body temperature (37°C) in the pulp chamber, a spiral shape 4 mm diameter copper tube was placed under the TCAP. These mechanisms provide more realistic results by stimulating blood circulation and maintaining the body temperature in the pulp chamber.

Examining multiple teeth in experiments may result in morphological and structural differences in enamel and dentin tissues, which could directly impact the thermal conductivity of the teeth. Therefore, the present study was performed on one sample tooth and without any bonding agent to remove composite resin easily from the cavity, in all groups. Furthermore, in the past research, it was reported that the adhesive systems have no significant effect in protecting the pulp from thermal stimuli.[20-22] These results justify that experiments could be carried out with one sample tooth and without the use of an adhesive system.

In the present study, the temperature increases in the pulp chamber during polymerization of composite resin when three different base cements were applied on the cavity floor were measured and compared with the intrapulpal temperature increases when no base material was applied, at body temperature (37°C) and by simulating pulpal blood microcirculation.The highest pulpal temperature rise values were measured in the group with no base material (group 4), as hypothesized at the beginning of the study. The mean Δt values measured in the PC and GIC base material applied groups (groups 1 and 2), were statistically significantly lower than in the no cement applied group (group 4). In addition, the pulpal temperature increases measured in the RMGIC base material applied group (group 3) were lower than in group 4, but the differences were not statistically significant. When the base material was applied, none of the mean Δt values measured in the pulp chamber exceed the critical temperature increase value of 5.5°C reported by Zach and Cohen.[2] However, in the group without the base material (group 4), the mean Δt value (5.76 ± 0.25) was above the critical value.

There have been few studies in the literature investigating the effectiveness of base cements in reducing the intrapulpal temperature increases caused by the polymerization process of composite resins. In a study examining the temperature changes in the pulp chamber during polymerization of composite resins, it was concluded that the effectiveness of RMGICs in protecting pulp from thermal stimuli was lower than calcium hydroxide-based cements and higher than flowable composite resins; however, this study was carried out at room temperature and without simulating pulpal blood microcirculation.[21]

Polycarboxylate cements are self-curing materials which can adhere chemically to tooth structures andshow high compatibility with the pulp tissue. Polyacrylic acid that is the liquid component of the material, is a weak acid and due to its large molecule structure it can not penetrate into the dentin tubules, so does not irritate pulp like other acids.[23-25] Using these properties, the material has been successfully used for many years in restorative dentistry. Likewise, glass ionomer cements are known for their advantages as chemical adhesion to the tooth tissues, ability to release fluoride and show no setting shrinkage under restorative procedures.[26,27] In addition, GIC shows thermal compatibility with tooth tissues because of low coefficients of thermal expansion similar to those of tooth structure.[28] However, the low mechanical strengths of existing conventional formulations of GICs limit their use in high-stress areas. Generally, the RMGICs are reported to have better mechanical properties than the conventional GICs.[29] RMGIC adheres chemically to the dentin tissue and provide a great tubule sealing. Furthermore, RMGIC inhibits hydrodynamic fluid flows and protects the pulp from thermal stimuli. These low thermal conductivity and tubule sealing properties make RMGIC a suitable pulp capping agent.[30] However, in the present study, RMGIC was not as effective as GIC and PC as a base cement in preventing the pulp from temperature increases during curing of composite resins.

The temperature changes obtained in this *in vitro* study, unfortunately, do not directly reflect the values that occur *in vivo* procedures. Temperatures exceeding 43°C stimulate the afferent nerve fibers andcause an increase in blood circulation so that the temperature moving towards the pulp chamber is distributed.[16] Also, other heat regulatory systems of the teeth as fluid motion in dentinal tubules or surrounding periodontal tissues may limit the increase in intrapulpal temperature. Nevertheless, clinicians should be aware of the possibility of damage due to a temperature increase in the pulp chamberduring light activated polymerization process of composite resin restorations.

CONCLUSION

Applying base cements under composite resins is significantly effective in reducing the temperature increases generated in the pulp tissue during the polymerization process. PC and conventional GIC have been found to be more effective than RMGIC in preventing the intrapulpal temperature increases during curing of composite resins.

CLINICAL SIGNIFICANCES

This research is important for providing to clinicians critical information about the temperature increases which may occur in the pulp during curing of composite resins and precautions to be taken. Applying a 2 mm thick self-curing base cement such as GIC or PC prevents the intrapulpal temperature increases. On the other hand, choosing the correct type LCU, decreasing the time of curing period, adjusting the correct distance between LCU and restoration surface will be worthwhile to protect the pulp tissue against hazards from thermal stimuli.

Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors.

Informed Consent

For this type of study, formal consent is not required.

ACKNOWLEDGMENT

We are thankful to Dr. Hande Senol for the statistical analyses of the study.

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