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 mm² 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/cm²). 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.

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 \textit{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.

\section*{MATERIALS AND METHODS}

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

\subsection*{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 $3 \times 4 \times 2 \ mm^3$ 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).

\subsection*{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 a data logger (DT-3891G; CEM, Shenzhen, PRC) which was connected to a computer for monitoring the temperature changes ($T$).

Pulpal blood microcirculation and temperature regulation of the teeth within physiological limits ($37\pm1\,^\circ\text{C}$) 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).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{fig1}
\caption{Schematic drawing of the mandibular premolar tooth and class V cavity with experimental microcirculation apparatus}
\end{figure}
In the groups 1–3, polycarboxylate cement (PC) (Spofo 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 with the same conventional composite resin material (Filtek Ultimate, 3M/ESPE, MN, USA) in all groups and were cured for equal time (20s) using Demi™ Plus Dental Curing LED Light (1200 mW/cm², Kerr Dental, Orange/CA, USA). In group 4 (control group), no base cement was applied, as expected. The highest changes in the groups are presented in Table 2. The mean and median values of calculated temperature changes (Δt) measured in each group were statistically significant between group 2 and group 4, and group 1 and group 4 (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 Δt 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 Cohen² 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

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.

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).
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. 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. 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.

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. 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. 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. 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 exceeded the critical temperature increase value of 5.5°C reported by Zach and Cohen. 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.

Polycarboxylate cements are self-curing materials which can adhere chemically to tooth structures and show 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. 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. In addition, GIC shows thermal compatibility with tooth tissues because of low coefficients of thermal expansion similar to those of tooth structure. 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.\textsuperscript{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.\textsuperscript{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 \textit{in vitro} study, unfortunately, do not directly reflect the values that occur \textit{in vivo} procedures. Temperatures exceeding 43°C stimulate the afferent nerve fibers and cause an increase in blood circulation so that the temperature moving towards the pulp chamber is distributed.\textsuperscript{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 chamber during 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.

**REFERENCES**

1. Langeland K. Effect of various procedures on the human dental pulp. Oral Surg Oral Med Oral Pathol 1961;14(2):210-233.
2. Zach L, Cohen G. Pulp response to externally applied heat. Oral Surg Oral Med Oral Pathol 1965;19(4):515-530.
3. McCabe JF. Cure performance of light-activated composites by differential thermal analysis. Dent Mater 1985;1(6):231-234.
4. Lloyd CH, Joshi A, McGlynn E. Temperature rises produced by light sources and composites during curing. Dent Mater 1986;2(4):170-174.
5. Masutani S, Setcos JC, Schnell RJ, et al. Temperature rise during polymerization of visible light activated resins. Dent Mater 1988;4(4):174-178.
6. Kuo WC, Chang YH, Lin CL, et al. Effects of different ceramic and dentin thicknesses on the temperature rise during photocuring. J Dent Sci 2011;6(4):210-215.
7. Murray PE, Smith AJ, Windsor IJ, et al. Remaining dentine thickness and human pulp responses. Int Endod J 2003;36(1):33-43.
8. Wataha JC, Lockwood PE, Lewis JB, et al. Biological effects of blue light from dental curing units. Dent Mater 2004;20(2):150-157.
9. Uhl A, Mills RW, Jandt KD. Polymerization and light-induced heat of dental composites cured with LED and halogen technology. Biomaterials 2003;24(10):1809-1820.
10. Brown W, Dewey W, Jacobs H. Thermal properties of teeth. J Dent Res 1970;49:752-755.
11. Kwon SJ, Park YJ, Jun SH, et al. Thermal irritation of teeth during dental treatment procedures. Restor Dent Endod 2013;38(3):105-112.
12. Kodonas K, Gogos C, Tziafas C. Effect of simulated pulpal microrotation on intrachamber temperature changes following application of various curing units on tooth surface. J Dent 2009;37(6):485-490.
13. Kodonas K, Gogos C, Tziafas D. Effect of simulated pulpal microrotation on intrapulpal temperature changes following application of heat on tooth surfaces. Int Endod J 2009;42(3):247-252.
14. Pohlo M, Scheinian A. Microscopic observations on living dental pulp. Acta Odontol Scand 1958;16(3):303-327.
15. Moon HJ, Lee YK, Lim BS, et al. Effects of various light curing methods on the leachability of uncurd substances and hardness of a composite resin. J Oral Rehabil 2004;31(3):258-264.
16. Raab WH. Temperature related changes in pulpal microrotation. Proc Finn Dent Soc 1992;88(Suppl 1):469-479.
17. Michalakis K, Pissiotis A, Hirayama H, et al. Comparison of temperature increase in the pulp chamber during the polymerization of materials used for the direct fabrication of provisional restorations. J Prostheth Dent 2006;96(6):418-423.
18. Yazici AR, Müftü A, Kugel G, et al. Comparison of temperature changes in the pulp chamber induced by various light curing units, \textit{in vitro}. Oper Dent 2006;31(2):261-265.
19. Kim S. Microcirculation of the dental pulp in health and disease. Journal of Endodontics 1985;11(11):465-471.
20. Hannig M, Bott B. In-vitro pulp chamber temperature rise during composite resin polymerization with various lightcur- ing sources. Dent Mater 1999;15(4):275-281.
21. Karatas O, Turel V, Bayindir YZ. Temperature rise during polymerization of different cavity liners and composite resins. J Conserv Dent 2015;18(6):431-435.
22. Yaşa E, Atalayın C, Karaçolak G, et al. Intrapulpal temperature changes during curing of different bulk-fill restorative materials. Dent Mater J 2017;36(5):566-572.
23. Smith DC. A new dental cement. Br Dent J 1968;124(9):381-384.
24. Diaz-Arnold AM, Vargas MA, Haselton DR. Current status of luting agents for fixed prosthodontics. J Prosthet Dent 1999;81(2):135-141.
25. Rosenstiel SF, Land MF, Crispin BJ. Dental luting agents: A review of the current literature. J Prosthet Dent 1998;80(3):280-301.
26. Xie D, Brantley W, Culbertson B, et al. Mechanical properties and microstructures of glass-ionomer cements. Dent Mater 2000;16(2):129-138.
27. Glasspoole EA, Erickson RL, Davidson CL. Effect of surface treatments on the bond strength of glass ionomers to enamel. Dent Mater 2002;18(6):454-462.
28. Wilson AD. Developments in glass-ionomer cements. Int J Prosthodont 1989;2(5):438-446.
29. Wilson AD. Resin-modified glass-ionomer cements. Int J Prosthodont 1990;3(5):425-429.
30. Souza PP, Aranha AM, Hebling J, et al. In vitro cytotoxicity and in vivo biocompatibility of contemporary resin-modified glass-ionomer cements. Dent Mater 2006;22(9):838-844.