Original Article

Bulk-Fill Restorative Materials in Primary Tooth: An Intrapulpal Temperature Changes Study

Abstract

Objectives: It was aimed to investigate the temperature changes in primary teeth pulp chamber during the curing/setting of bulk-fill restorative materials with different nanoparticle contents. **Methods:** Twenty-five extracted, primary mandibular second molars were prepared as a Class II cavity. Five bulk-fill restorative materials consisting of Equia Fil (HVGIC), glass carbomer (GC) cement, Sonic Fill (SF), X-tra Fil (XF), and Quix Fil (QF) were tested. The measurement of the pulp chamber temperature changes (starting temperature 37°C) during setting/curing was performed with a J type thermocouple. The data, differences between highest and initial temperature values, were recorded and analyzed by one-way ANOVA. **Results:** The temperature changes in the pulp chamber were in EF (2.81°C), GC (7.92°C), SF (3.33°C), XF (3.43°C), and QF (3.02°C). There were statistically significant differences between temperature changes in groups ($P < 0.05$). **Conclusion:** The tested bulk-fill resin composites and high-viscosity glass ionomer cement do not increase the intrapulpal temperature in primary teeth during the curing/setting.

Keywords: *Bulk-fill, glass carbomer, intrapulpal temperature, primary tooth, restorative materials*

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Introduction

Dentists need restorative materials to use fast and easily, reduce the chair time, decrease the contamination risk of cavity, and increase the patient cooperation, especially in disabled and handicapped children.[1,2] Simplification of treatment steps supports uninterrupted maintenance of treatment and might also be important in pediatric dentistry.[1] A new attempt to simplify and decrease the multistep procedures is called bulk-fill restorative materials. Introduced materials include high-viscosity glass ionomer cements (HVGICs), resin-modified glass ionomer cements, self-adhesive resin cements, glass carbomer (GC) cements, and bulk-fill composite (BC) resins.[3-6]

Glass ionomer cements have been successfully used in pediatric patients due to their chemical bond to enamel and dentin, ability to release fluoride, similar thermal expansion as dentin and high remineralization capacity.[7-9] However, GICs have some disadvantages as lower resistance, marginal deficiencies, and limited indication in Class II cavities. Various formulas and modifications have been developed to overcome the deficiencies of conventional GICs.[10] One of them is HVGIC system. Reduction of the size of glass particles in the matrix of conventional GIC and increasing the powder ratio enable GIC to become packable and take a bulk-fill form.[10,11] In recent years, another new material has been developed from glass ionomer cement, GC, which contains nanosized glass and fluoro/hydroxyapatite particles that support the remineralization. Polydialkylsiloxane in GC improves the physical properties of restorative material. The clinical application of GC is similar to that of conventional GICs, except thermo-light application during the setting reaction.[12] Heat can be applied with special light-curing device (CarboLED) during setting in GC.

Composite resins are widely used for Class I, II and III, IV, V cavity types in anterior and posterior teeth. High strength, hardness, modulus elasticity, low thermal conductivity, and superior esthetics are advantages of composites. However, they have some major disadvantages such as difficulty in direct access to the curing light and inadequate light penetration in deep cavities, especially in Class II restorations. The most common method for maximum polymerization to be ensured is the fact

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that the thickness of composite resin to be cured should not exceed 2.5 mm.[13] Recently, BCs have been developed to reduce the incremental technique steps.[1,2] BCs can be placed and light cured in one layer of up to a thickness of 4–5 mm.[1-5] BCs are a type of new generation nanohybrid resin composite. Its content generally includes ytterbium trifluoride, barium glass, mixed oxide, proacrylate, and zirconium/silica particles.[14] These particles provide that the effect of the light cure unit that will increase the radiopacity reaches to deep.[15]

Different light/thermo-light of varying power outputs are used during the curing/setting of bulk-fill restorative materials. The factors that can affect the temperature changes in the pulp chamber are light source type, intensity, and activation time.[16] Blue light-emitting diodes (LED), the most common type of visible light activation unit, is used to cure composite resin. High-intensity LED, which was introduced to allow curing time reduction for sufficient polymerization, has 1400 mW/cm^2, 395–480 nm for 10 s. For setting of GC, CarboLED (GCP Dental, Holland) CarboLED is operated at 1400 mW/cm^2, 470 nm, and reaches to 54°C in 40 s. The recommended polymerization time for the GC is between 60 and 90 s.[17] The temperature increase in the pulp chamber significantly affects the vitality of pulp. In their study on monkeys, Zach and Cohen[18] found that a temperature increase of 5.5°C in pulp chamber for 10 s led to the loss of vitality on the pulp tissue by 15%. Pohto and Scheinin[19] determined that the critical temperature for irreversible damage to pulp begins at 42–42, 5°C. An increase in temperature in the tooth, which may consequently damage the dental pulp, is caused by an exothermic curing reaction of light-activated restorative materials or acid-base setting of HVGIC and heat absorption by tooth from the irradiation of light-curing units (LCUs).

The effect of high temperature increase associated with bulk-fill restorative materials has been enlightened in recent years. In this study, it was aimed to investigate the temperature changes in microcirculation model in primary teeth pulp chamber in Class II cavity during the polymerization of bulk-fill restorative materials. The null hypothesis was that there would be no statistically significant difference between the pulpal temperature changes during the curing/setting of five different bulk fill restorative materials.

Methods

This study was approved by the Research Ethics Committee of Mustafa Kemal University, report no: 05058.

Thermal changes in pulpal cavity

Twenty-five extracted, caries-free, primary mandibular second molars were used in this study. The roots were removed 2 mm beneath the cement-enamel junction. Then, all organic remnants in the pulpal chambers were cleaned using a 5.25% sodium hypochlorite solution. The teeth were prepared as Class II cavity. Cavity preparations were done by two steps; approximal box (only mesial) and occlusal cavity. The small diamond round (1/2 round) bur was used to remove the enamel in occlusal surface. The diamond fissure bur was used to remove the dentin in 4 mm depth in approximal box. The height × width × length dimensions of the cavity are 4 × 3 × 4 [Figure 1]. Dimensions of occlusal cavity are prepared in 2 mm width and 3 mm length. Angles of walls and floors should be slightly rounded. One millimeter of dentin remained between the pulp chamber and the axial wall and pulpal floor, which were measured with a caliper and assessed radiographically. The prepared teeth were kept wet in distilled water for protection from dehydration.

The pulpal microcirculation model, which was originally designed by Savas *et al*.,[20] was used. The fluid flow rate of the system was set and kept constant at 1 ml/min using a digital infusion flowmeter (SK-600II infusion pump, SK Medical, Shenzhen, China). Distilled water at 37°C temperature was used to simulate blood and blood pressure in the pulp at 15 cm H_2O [Figure 2].

A heat-transfer unit (ILC P/N 213414; Wakefield Engineering, Beverly, MA) was applied to the tip of the thermocouple wire, which was fixed with light-curing glass ionomer cement (Calcimol LC; Voco GmbH, Cuxhaven, Germany) to maintain contact with the pulp chamber. Thus, the gap around the thermocouple wire was sealed to prevent leakage from the system [Figure 2]. The materials and LCUs used in this study are shown in Tables 1 and 2. The bulk-fill restorative materials (Equia Fil (HVGIC), GC, Sonic Fill [SF], X-tra Fil [XF], Quix Fil [QF]) were applied to the cavity in one step and cured with Valo LED in 1000 Mw/cm^2, except GC group. GC cement was cured with GCP Carbo LED thermo-cure lamp (GCP, Netherlands) in 1400 mW/cm^2. A special transparent matrix system (Supermat, Kerr, USA) was used to keep the bulk-fill materials (4 mm) in Class II cavity.

The teeth were randomly divided into five equal groups, and five teeth (n = 5) were used for each group. Temperature was measured with a thermocouple, which was connected to a data logger (XR440-M Pocket Logger, Pace Scientific, NC, USA) to record the temperature increase values from the pulp chamber during curing/setting. The results were monitored in graphic forms and in real time and transferred to a computer. Later, the difference between the first and highest temperature values (Δt) was calculated.

Statistical analysis

Analysis was performed using the SPSS statistical software (Statistical Package for the Social Sciences; SPSS Inc, Chicago, IL, USA). The recorded data were analyzed by one-way ANOVA. Tukey's honest significant difference test was used to compare temperature changes.

Table 1: Material properties used in this study

Materials	Material code	Manufacturer	Materials content	Filler weight %, volume %	Polymerization time	Polymerization type
Equia Fil	HVGIC	GC, Japan	Polyacrylic acid, aluminosilicate glass, distilled water		-	Chemical
GlassFil	GCP	GCP, Netherlands	Nanofluoro hydroxyapatite, liquid silica		90-120 s	Light and heat
Sonicfill	SF	Kerr, USA	Resin: Bis-GMA, Bis-EMA, TEGDMA Filler: Silanated barium boron aluminum	84/66	20 s	Light
Xtra Fill	XF	Voco, Germany	Resin: Bis-GMA, UDMA, TEGDMA Filler: Barium boron aluminum silicate glass	86/70	20 s	Light
QuixFil	QF	Dentsply, Germany	Resin: Bis-EMA, UDMA, TEGDMA, TMPTMA Filler: Silanated strontium aluminum sodium fluoride phosphate silicate glass	86/66	10 s	Light

Bis-GMA: Bisphenol-A-glycidyldimethacrylate; Bis-EMA: Ethoxylatedbisphenol A dimethacrylate; UDMA: Urethane dimethacrylate; TEGDMA: Triethylene glycol dimethacrylate; TMPTMA: Trimethylolpropane trimethacrylate; HVGIC: High-viscosity glass ionomer cements; SF: Sonic Fill; XF: X-tra Fil; QF: Quix Fil; GC: Glass carbomer cement

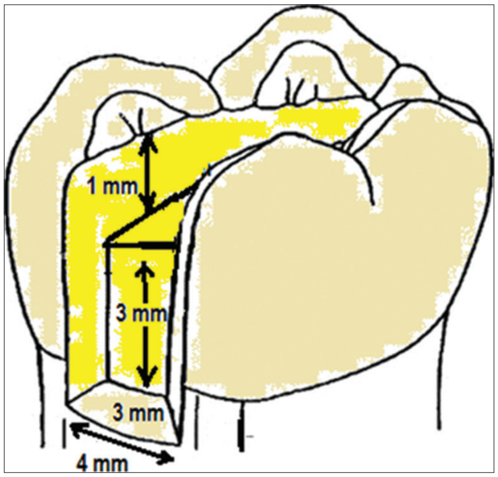

Figure 1: Dimensions of the cavity preparation

Results

The mean maximum temperature changes and standard deviation for all tested materials were presented in Table 3. There were statistically significant differences between temperature changes in the groups ($P < 0.05$). The highest temperature changes (7.92°C ± 1.2°C) in the pulp chamber were recorded in GC group during thermal-light setting ($P < 0.05$). The mean temperature changes of SF, XF, and QF were 3.33°C ± 1.2°C, 3.43°C ± 0.8°C, 3.02ºC ± 0.2°C, respectively, and no statistically significant differences were exhibited among bulk-fill composite resins. The lowest mean temperature changes (2.81oC ± 0.5°C) was seen in Equia Fil.

Discussion

Today, bulk-fill restorative materials based on fast application have become popular. However, possible pulpal damage during the setting/curing of the bulk-fill restorative materials in deep cavity in primary and permanent tooth is a matter of concern.[21] Temperature increase in the pulp chamber during operative procedures can affect negatively the health of vital pulp.[16-19] Many factors can be connected with contents of dental restorative materials, type of LCU, light intensity of the LCU, exposure time to LCU, and thickness of the remaining dentin.[19-21] This present study is a pioneer to evaluate the temperature changes in pulpal chamber with microcirculation model during the setting/curing of the bulk-fill restorative materials with different contents and with appropriate LCU systems in Class II cavity in primary tooth.

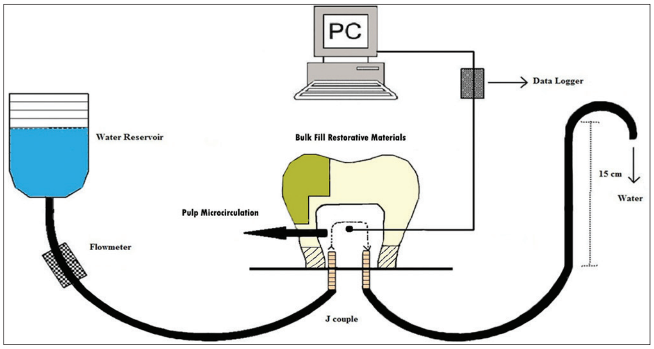

Figure 2: Schematic diagram of the measurement of intrapulpal temperature changes

To measure the change in intrapulpal temperature, the empty pulp cavity was first used.[22] However, as this test model ignored the soft pulp tissue factor in the chamber, microcirculation test model was required to be developed. Tooth pulp has an extensive vascular supply, and this structure plays an important role in absorption of temperature increase when the dental tissue affected by a thermal stimulus.[23] An alternative way to measure intrapulpal temperature increases was devised; that is, a mechanism for substituting pulpal blood which was developed by linking a pump with a 0.0125 flow rate to

Table 2: Light-curing unit used in the present study

LCU	Manufacturer	Mode	Light intensity
Valo LED	Ultradent Products Inc, South Jordan, UT, USA	Standard mode	1000 mW/cm^2
CarboLED heat-cure lamp	GCP dental, Netherlands	-	1400 mW/cm^2

LED: Light-emitting diodes; LCU: Light-curing unit

Table 3: Mean values of mean temperature changes of the groups

Groups	Mean temperature changes±SD
HVGIC	2.81±0.5^a
GC	7.92±1.2^b
SF	3.33±1.2^a
XF	3.43±0.8^a
QF	3.02±0.4^a

$^{a,b}P<0.05$; HVGIC: High-viscosity glass ionomer cements; SF: Sonic Fill; QF: Quix Fil; SD: Standard deviation; GC: Glass Carbomer; XF: Extra-fil

one of the roots through a small-diameter tube. Attrill *et al*.[24] placed a "pulp-like tissue" into the pulp cavity to substitute for vital pulp; Hannig and Bott[16] mounted the sample tooth in a water bath (37°C ± 0.1°C). At last, the pulp blood microcirculation (PBM) method is preferred at present for *in vitro* testing of temperature changes. The PBM apparatus circulates water in the pulp chamber at a rate of 0.026 ml/min to simulate *in vivo* conditions. Water flow at body temperature in microcirculation model is used to reflect the dental pulp.[25] Studies have shown that higher temperature increases are obtained when the pulp microcirculation model is not used.[24-27] In this study, the microcirculation model was used to simulate the vascular tissue in the pulp and to provide realistic results.

HVGICs are set by an acid-base reaction which is an exothermic reaction.[28,29] After mixing powder and liquid, setting mechanism begins; protons in aqueous solutions of polymeric acids attack the glass particles and cations (calcium and aluminum). The setting of glass ionomer is a complex process consisting of initial gelation and maturation phases. Al^{+3} and Ca^{+2} ions are cross-linking with polycarboxylate chains.[30] For HVGICs, the application of heat has been shown to improve the physicomechanical properties and clinical performance, as well as surface hardness, bond strength to enamel, and marginal adaptation.[12,29] The application of heat from the outside of the glass ionomer cement during the setting reaction allows the acid present in the liquid to become more active and to further react with glass filler particles and to degrade them. This leads to an increase in the amount of ion release and diffusion from the glass particles. A more reactive acid and more ion release and increased diffusion allow rapid formation of the calcium polyacrylate matrix. This increases the mechanical properties of the material as a result of the initial reaction.[31] In the literature, it is known that glass ionomer cements have low heat conductivity and have good thermal insulators[17] In this study, the lowest temperature changes were observed in HVGIC group, 2.81°C with ValoLED for 20 s. Our study, consistent with other studies, showed low intrapulpal temperature in the HVGIC, and the results did not affect negatively the vitality of pulp.[17,21]

The GC cement is a type of glass ionomer-added bioactive material, and the setting mechanism of GC is similar to the glass ionomer cement.[12] GCP is setting in an autopolymerization mode that is the reaction of the glass and aqueous polyacrylic acid components in a neutralization reaction. High energy light-curing device (CarboLED) is recommended to accelerate the acid-base reaction of GC, not to promote the photochemical reaction and CarboLED application, and the temperature of LED system reaches 54°C–60°C.[12] In our study, GC and HVGIC groups showed different pulpal temperature increases in response to heat. The highest pulpal temperature increase was determined in GC while the lowest temperature increase was determined in HVGIC. Consequently, the null hypothesis was rejected as temperature changes were observed among groups. Kahvecioglu *et al*.[32] measured the intrapulpal changes during the setting of GC in Class I cavity in primary and permanent teeth. Highest temperature rise was observed in GC group, but all group results were under the critical temperature pulp health. Botsali *et al*.[6] evaluated the temperature changes using GC and two resin-modified glass ionomer restorative materials in different dentin thickness. It was reported that the highest temperature changes were observed in GC with CarboLED in class I cavity in permanent teeth. The reaction of GIC to heat varies with powder-liquid ratio and content in the matrix.[33] This difference may be resulted from the high glass content in GC, unlike other GICs, due to its nanofluorapatite structure. In addition, long high energy light-curing device application time (60 s) may be possible explanation for the high pulpal temperature changes of GC compared to other bulk-fill restorative materials tested in the present study.

BCs are composites that can be placed in a single layer of 4–5 mm thickness in a cavity.[1-3] Available BCs consist of polymeric matrix, filler, and interphase phases. The basic monomers/oligomers used in the polymeric matrix phase are triethylene glycol dimethacrylate, A-glycidyl dimethacrylate, and urethane dimethacrylate. Common fillers are silica compounds (silicate-based glasses, pyrogenic silica, and barium aluminum silicate), zirconia, quartz, and alumina. The organosilanes in the interphase is bonded chemically to the matrix and fillers to increase the mechanical properties.[32] BCs are more translucent due to larger filler size than conventional composite resins. BCs are classified into two basic groups; flowable and higher viscosity paste materials.[27] XF, QF, and SF are bulk-fill higher viscosity paste composites, and SF is replaced to the cavity with a sonic handpiece.[27,30] The weight/volume ratios and contents of inorganic filler particles of the bulk-fill composite resins that used in the present study are XF 86/70 (barium boron aluminum silicate glass), QF 86/66 (strontium aluminum sodium fluoride phosphate silicate glass), and SF 84/66 (silanated barium boron aluminum).

In our study, temperature increases in all BCs were <5.5°C, the estimated critical temperature for pulp vitality. The results of the present study demonstrated no significant differences among three different BCs tested in thermal changes. There are only a few studies in the literature regarding BCs that include thermal changes in permanent tooth, not in primary tooth and not with the tested composites in this present study.[31,32] Yasa *et al*.[21] reported that different BCs (Filtek Bulk Fill Posterior, 11.59 ± 2.12; SDR 12.83 ± 1.53) showed higher temperature changes compared to GC (10.74 ± 1.14) and HVGIC (3.56 ± 0.84). Light-curing BCs with low filler content and amount of filler exhibited high temperature changes. The fact that pulpal temperature changes were different on an average and statistical similarity may be explained by the fact that the filler ratios and resin matrix were closed to each other. According to the present data, bulk-fill resin composite having high filler is used safely in deep cavities both primary teeth.

Conclusion

BCs and high-viscosity GIC presented low temperature changes in the Class II restorations on primary molars. The highest temperature changes were observed in GC with the CarboLED system in primary teeth. Longer curing times of GC or higher heat application can be reduced to avoid damage to the vitality of the pulp.

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Conflicts of interest

There are no conflicts of interest.

References

1. Ilie N, Schöner C, Bücher K, Hickel R. An *in-vitro* assessment of the shear bond strength of bulk-fill resin composites to permanent and deciduous teeth. J Dent 2014;42:850-5.
2. Gaintantzopoulou MD, Gopinath VK, Zinelis S. Evaluation of cavity wall adaptation of bulk esthetic materials to restore class II cavities in primary molars. Clin Oral Investig 2017;21:1063-70.
3. Czasch P, Ilie N. *In vitro* comparison of mechanical properties and degree of cure of bulk fill composites. Clin Oral Investig 2013;17:227-35.
4. Ilie N, Keßler A, Durner J. Influence of various irradiation processes on the mechanical properties and polymerisation kinetics of bulk-fill resin based composites. J Dent 2013;41:695-702.
5. Ülker HE, Erkan AI, Günaydın N, Kahvecioğlu F, Ülker M. Comparison of the mechanical and biological properties of self-adhering materials. J Adhes Sci Technol 2016;30:1119-30.
6. Botsali MS, Tokay U, Ozmen B, Cortcu M, Koyuturk AE, Kahvecioglu F, *et al.* Effect of new innovative restorative carbomised glass cement on intrapulpal temperature rise: An *ex-vivo* study. Braz Oral Res 2016;30. pii: S1806-83242016000100261.
7. Wilson AD, Kent B. The glass-ionomer cement, a new translucent dental filling material. J Chem Technol Biotechnol 1971;21:313.
8. Lohbauer U. Dental glass ionomer cements as permanent filling materials? Properties, limitations and future trends. Materials 2009;3:76-6.
9. Xie D, Brantley WA, Culbertson BM, Wang G. Mechanical properties and microstructures of glass-ionomer cements. Dent Mater 2000;16:129-38.
10. Horváth A, Papp Z, Dobó-Nagy C, Gera I. Clinical examination of the gingival effects of three glass ionomer restorative materials (GC fuji IX GP, GC fuji IX GP EXTRA és GC EQUIA). Fogorv Sz 2014;107:125-30.
11. Gurgan S, Kutuk ZB, Ergin E, Oztas SS, Cakir FY. Four-year randomized clinical trial to evaluate the clinical performance of a glass ionomer restorative system. Oper Dent 2015;40:134-43.
12. Gorseta K, Borzabadi-Farahani A, Moshaverinia A, Glavina D, Lynch E. Effect of different thermo-light polymerization on flexural strength of two glass ionomer cements and a glass carbomer cement. J Prosthet Dent 2017;118:102-7.
13. Fronza BM, Rueggeberg FA, Braga RR, Mogilevych B, Soares LE, Martin AA, *et al.* Monomer conversion, microhardness, internal marginal adaptation, and shrinkage stress of bulk-fill resin composites. Dent Mater 2015;31:1542-51.
14. Zorzin J, Maier E, Harre S, Fey T, Belli R, Lohbauer U, *et al.* Bulk-fill resin composites: Polymerization properties and extended light curing. Dent Mater 2015;31:293-301.
15. Flury S, Peutzfeldt A, Lussi A. Influence of increment thickness on microhardness and dentin bond strength of bulk fill resin composites. Dent Mater 2014;30:1104-12.
16. Hannig M, Bott B. *In-vitro* pulp chamber temperature rise during composite resin polymerization with various light-curing sources. Dent Mater 1999;15:275-81.
17. Gavic L, Gorseta K, Glavina D, Czarnecka B, Nicholson JW. Heat transfer properties and thermal cure of glass-ionomer dental cements. J Mater Sci Mater Med 2015;26:249.
18. Zach L, Cohen G. Pulp response to externally applıed heat. Oral Surg Oral Med Oral Pathol 1965;19:515-30.
19. Pohto M, Scheinin A. Microscopic observations on living dental pulp. Acta Odontol Scand 1958;16:303-27.
20. Savas S, Botsali MS, Kucukyilmaz E, Sari T. Evaluation of temperature changes in the pulp chamber during polymerization of light-cured pulp-capping materials by using a VALO LED light curing unit at different curing distances. Dent Mater J 2014;33:764-9.
21. Yasa E, Atalayin C, Karacolak G, Sari T, Turkun LS. Intrapulpal temperature changes during curing of different bulk-fill restorative materials. Dent Mater J 2017;36:566-72.
22. Daronch M, Rueggeberg FA, Hall G, De Goes MF. Effect of composite temperature on *in vitro* intrapulpal temperature rise. Dent Mater 2007;23:1283-8.
23. Hussey DL, Biagioni PA, Lamey PJ. Thermographic measurement of temperature change during resin composite polymerization *in vivo*. J Dent 1995;23:267-71.
24. Attrill DC, Davies RM, King TA, Dickinson MR, Blinkhorn AS. Thermal effects of the Er: YAG laser on a simulated dental pulp:

A quantitative evaluation of the effects of a water spray. J Dent 2004;32:35-40.

25. Tosun G, Usumez A, Yondem I, Sener Y. Temperature rise under normal and caries-affected primary tooth dentin disks during polymerization of adhesives and resin-containing dental materials. Dent Mater J 2008;27:466-70.
26. Sari T, Celik G, Usumez A. Temperature rise in pulp and gel during laser-activated bleaching: *In vitro*. Lasers Med Sci 2015;30:577-82.
27. Al-Qudah AA, Mitchell CA, Biagioni PA, Hussey DL. Thermographic investigation of contemporary resin-containing dental materials. J Dent 2005;33:593-602.
28. Hill R, Wilson A. Some structural aspects of glasses used in ionomer cements. Glass Technol 1988;29:150-8.
29. Borzabadi-Farahani A, Lynch E. Influence of thermo-light curing with dental light-curing units on the microhardness of glass-ionomer cements. Int J Periodontics Restorative Dent 2016;36:425-30.
30. Wasson EA, Nicholson JW. New aspects of the setting of glass-ionomer cements. J Dent Res 1993;72:481-3.
31. Woolford MJ. Effect of radiant heat on the surface hardness of glass polyalkenoate (ionomer) cement. J Dent 1994;22:360-3.
32. Kahvecioglu F, Tosun G, Ülker HE. Intrapulpal thermal changes during setting reaction of glasss carbomer using thermocure lamp. BioMed Res Int 2016. [Doi: 10.1155/2016/5173805].
33. Olegário IC, Kim SS, Hesse D, Tedesco TK, Calvo AF, Raggio DP. Mechanical properties of high-viscosity glass ionomer cement and nanoparticle glass carbomer. J Nanomater 2015;16:37.