Original Article

Comparison of temperature change among different adhesive resin cement during polymerization process

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Abstract

Purpose: The aim of this study was to assess the intra-pulpal temperature changes in adhesive resin cements during polymerization.

Materials and Methods: Dentin surface was prepared with extracted human mandibular third molars. Adhesive resin cements (Panavia F 2.0, Panavia SA, and RelyX U200) were applied to the dentin surface and polymerized under IPS e.max Press restoration. K-type thermocouple wire was positioned in the pulpal chamber to measure temperature change ($n = 7$). The temperature data were recorded (0.0001 sensible) and stored on a computer every 0.1 second for sixteen minutes. Differences between the baseline temperature and temperatures of various time points (2, 4, 6, 8, 10, 12, 14, and 16 minute) were determined and mean temperature changes were calculated. At various time intervals, the differences in temperature values among the adhesive resin cements were analyzed by two-way ANOVA and post-hoc Tukey honestly test ($\alpha = 0.05$).

Results: Significant differences were found among the time points and resin cements ($P < 0.05$). Temperature values of the Pan SA group were significantly higher than Pan F and RelyX ($P < 0.05$).

Conclusion: Result of the study on self-adhesive and self-etch adhesive resin cements exhibited a safety intra-pulpal temperature change.

Key Words: Adhesive, polymerization, resin cement, temperature change, thermocouple

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INTRODUCTION

In dentistry, resin-based materials generally require light activation for the polymerization.[1] However, light curing causes a temperature increase because of light energy absorption and exothermic polymerization reaction within resin. The increase of temperature may be a detrimental potential effect on the pulpal tissue.[2,3] The potentially harmful effect of temperature level within the pulp tissue has been a concern for many years.[4-8] During the restorative treatment, in case of intrapulpal temperature exceeding 42.5°C, irreversible pulpal damage may develop in the pulp tissue.[9,10] Zach and Cohen[9] reported that in Macaca rhesus monkeys, a rise of 5.5°C intrapulpal temperature induced necrosis in 15%, a rise of 11°C induced necrosis in 60%, and a rise of 16°C induced necrosis in 100% of

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the tested teeth. However, Baldissara *et al*.[11] observed that the pulp is less sensitive to thermal damage. They evaluated thermal damage thresholds in human teeth and noted that an average increase of 11.2°C intrapulpal temperature did not damage the pulp, and no signs of inflammation were observed. Histological evidence of thermal damage and reversible pulpitis was detected in the teeth monitored between 60 and 91 days.[11]

The use of high-speed handpiece during tooth preparation or an exothermic reaction during the polymerization of resin-based restorative materials such as composite resin and acrylic resin may change intrapulpal temperature.[12-14] The exothermic reaction change in the intrapulpal temperature depends on various factors such as the light unit type, exposure time, density, distance between the light source and the pulp,[15-19] composite shade, thickness, remaining dentin,[20-23] and the movement of blood or other fluids in the pulp.[24]

Adhesive resin cement is essential for cementation of ceramic restorations. Adhesive cementation to enamel or dentin requires the use of an adhesive system followed by the application of resin cement. Adhesive systems can be classified as either self-etch or total-etch.[25-28] Self-etch systems are popular among clinicians due to their ease of use, but they have exhibited a lower bond strength to enamel than that of total-etch systems, which are still the gold standard.[29] However, the total-etch system requires etching, priming, and bonding; it is complex and it needs technique sensitive and more time. Therefore, dental practice needs have led to the recent development of self-adhesive resin cement that eliminates the multistep bonding procedure. Like conventional cement, self-adhesive resin cement is applied in a single step.[22-2525-28]

In spite of the widespread use of adhesive resin cement, little information is available about their exothermic reaction. Therefore, the purpose of the present study was to compare the temperature changes of self-etch and self-adhesive resin cement under the IPS e.max Press restoration during the polymerization process.

The authors hypothesized that (1) adhesive resin cement used in the present study has similar temperature increase values and (2) there are no differences in the temperature increase values of resin cement at different time points.

MATERIALS AND METHODS

Twenty-one extracted, noncarious human mandibular third molars were selected, cleaned from soft tissues, and stored in 0.5% chloramine-T at 4°C for 1 week. The extracted teeth were then stored in distilled water during the study. For temperature measurements, the roots of the molars were removed, approximately 2 mm below the cementoenamel junction and perpendicular to the long axis of the teeth, with a slow-speed diamond saw (IsoMet, Buehler, Lake Bluff, IL, USA). The pulpal soft tissues were removed using curettes. To prepare dentin surface, the occlusal enamels of all extracted teeth were removed under water cooling using the slow-speed diamond saw. The dentin specimens were standardized at approximately 2 mm thickness from the highest pulp horn, as measured with a caliper (Kumpas Metal Iwanson, Jensen, Metzingen, Germany). The root of teeth was placed in an acrylic plastic base (20 mm diameter and 5 mm height) with an autopolymerizing acrylic resin (Imicryl SC, Imicryl, Konya, Turkey). A hole providing entrance for thermocouple wire into the pulp was created at the center of acrylic plastic base. The thermocouple wire was placed below the pulpal chamber of the highest pulp horn, in contact with the dentin [Figure 1]. To stabilize the thermocouple wire position and transfer heat from dentin surface, silicone transfer compound (ILC P/N 213414, Wakefield Engineering, MA, USA) was injected into pulp chamber.

One self-etch adhesive resin cement (Pan F) (Panavia F 2.0, Kuraray Noritake Dental Inc., Okayama, Japan) and two types of self-adhesive resin cement (RelyX) (RelyX U200, 3M ESPE, 3M Deutschland GmbH, Germany) and (Pan SA) (Panavia SA Cement, Kuraray Noritake Dental Inc.) were used in the present study. One hundred micrometer thick, black Teflon sheets (20 mm × 20 mm) with a hole (10 mm diameter) at the center were used as spacers for resin cement on dentin surface. The adhesive resin cement was adhered to the dentin surface under IPS e.max Press restoration (15 mm diameter and 1 mm thickness) [Figure 2]. According to the manufacturer's instruction, resin cement was polymerized with a light source (HS LED 1500, Henry Schein Inc., Melville, USA) distanced between adhesive resin cement 10 mm [Table 1]. All adhesive resin cement was tested at 23°C ± 2°C and 50% ± 5% relative humidity.

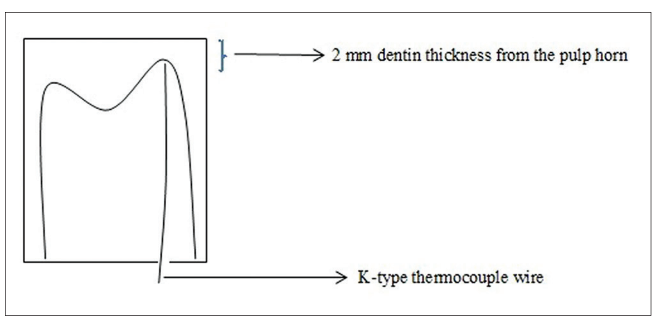

Figure 1: View of perpendicular section of tooth sample

The temperature changes were measured with a K-type thermocouple wire connected to a digital thermometer (USB-2416, Measurement Computing, Norton, USA). The output from the digital thermometer was fed to a chart recorder (MCC DAQ Hardware); thus, the temperature values were transferred to a computer in real time. The values of temperature were recorded (0.0001 sensible) and stored on a computer every 0.1 s for 16 min. Differences between the baseline temperature and temperatures of various time points (2, 4, 6, 8, 10, 12, 14, and 16 min) were determined, and mean temperature changes were calculated.

The differences in temperature values among the adhesive resin cement were analyzed using two-way repeated measures ANOVA at the eight time points, followed by *post hoc* Tukey honestly test ($\alpha = 0.05$). The statistical analyses were performed with SPSS statistical software (SPSS version 16.0; SPSS Inc., Chicago, IL., USA).

RESULTS

The statistically significant differences were found for adhesive resin cement, time points, and their interactions ($P < 0.05$). Plotting of the temperature change is presented in Figure 3, and during polymerization, mean (standard deviation) temperatures of difference values of the adhesive resin cement are presented in Table 2.

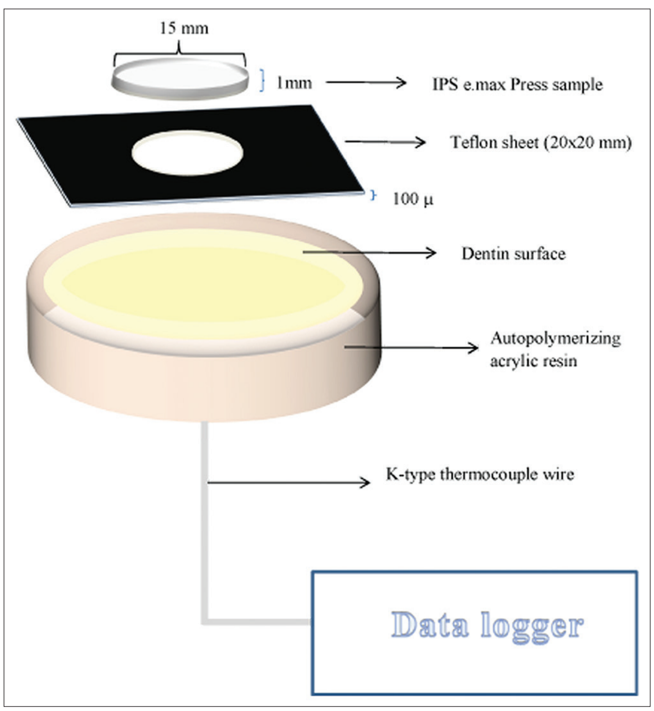

Figure 2: Schematic view of temperature rise measurement during polymerization of adhesive resin cement under IPS e.max Press restoration

The difference in temperature value of the Panavia SA group was statistically significantly higher than Pan F and RelyX group ($P < 0.05$). No significant differences were found between the Pan F group and RelyX group ($P > 0.05$). The highest difference in temperature value was observed in the Pan SA group and the lowest value was observed in the RelyX group. In addition, during polymerization, a statistically significant difference was noted among time points ($P < 0.05$). The highest temperature increase was observed in the 2nd min and the lowest one was observed in the 16th min.

In the 2nd min, Pan F (2.43°ΔC) showed the highest temperature increase followed by Pan SA (2.29°ΔC) and RelyX (1.71°ΔC). In the 4th min, Pan F (2.06°ΔC) and Pan SA (2.05°ΔC) showed nearly same difference followed by RelyX (1.37°ΔC). In the other time points, the highest temperature increase was found in Pan SA group. In addition, all cement groups showed no significant difference in the 14th and 16th min ($P > 0.05$).

DISCUSSION

The present study compared the temperature changes of self-etch and self-adhesive resin cement during polymerization. The first hypothesis, adhesive resin cement used in the present study has similar temperature increase values, was rejected. The second hypothesis, there are no differences in the temperature increase values of resin cement at different time points, was also rejected.

Heat has been identified as a primary cause of pulpal damage.[30] Dentin has a low thermal conductivity; however, during excess preparation for ceramic restorations, the potential for pulp injury is greater due to the increase in

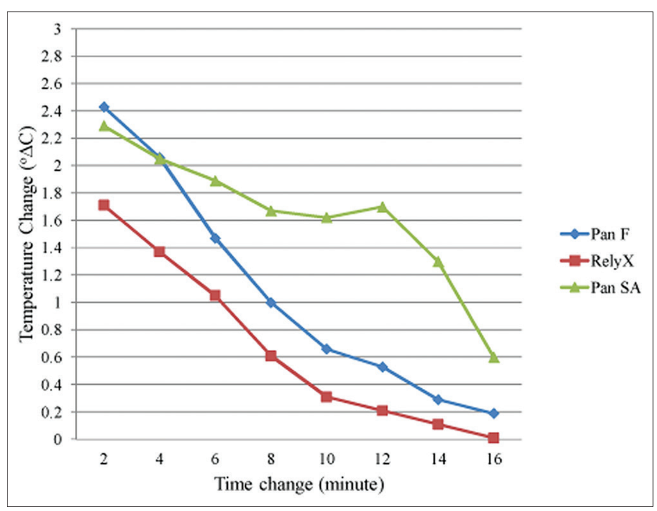

Figure 3: Linear graph of temperature difference values (°ΔC) of adhesive resin cement

Table 1: Manufacturer, code and light-curing time according to the manufacturer's instruction

Resin cement	Codes	Manufacturer	Cementation procedure of tooth surface	Light-curing time
Panavia F2.0	Pan F	Kuraray Noritake Dental Inc., Okayama, Japan	-Apply mixed ED PRIMER II and wait for 30 second. Air-dry gently -Mix paste A and B. Apply the mixture -Apply light-curing.	20 second LED (Light intensity >300 mW/cm^2, wavelength range 400-515 nm)
Panavia SA	Pan SA	Kuraray Noritake Dental Inc., Okayama, Japan	-Apply the mixed paste over the entire tooth surface -Apply light-curing	10 second LED (Light intensity 800-1400 mW/cm^2, wavelength range 400-515 nm)
RelyX U200	RelyX	3M ESPE, 3M Deutschland GmbH, Germany	-Mix cement. Apply cement to the prepared tooth surface -Apply light-curing	20 second LED (Light intensity 800-1400 mW/cm^2, wavelength range 400-500 nm)

Table 2: Mean (SD) temperature difference values (°ΔC) of the adhesive resin cements during polymerization

Adhesive resin cements	Time points (minute)							
	2	4	6	8	10	12	14	16
Panavia F 2.0	2.43^{Aa} (0.83)	2.06^{Aa} (0.64)	1.47^{Aa} (1.40)	1.0^{Aa} (0.41)	0.66^{Aa} (0.23)	0.53^{Aa} (0.16)	0.29^{Ab} (0.07)	0.19^{Ab} (0.01)
RelyX U200	1.71^{Aa} (1.40)	1.37^{Aa} (0.93)	1.05^{Aa} (0.58)	0.61^{Aa} (0.32)	0.31^{Aa} (0.14)	0.21^{Aa} (0.02)	0.11^{Ab} (0.02)	0.01^{Ab} (0.001)
Panavia SA	2.29^{Ba} (1.02)	2.05^{Ba} (1.6)	1.89^{Ba} (2.04)	1.67^{Ba} (2.12)	1.62^{Ba} (2.08)	1.70^{Ba} (1.78)	1.30^{Bb} (1.19)	0.60^{Bb}(0.54)

According to Tukey test, capital letters indicate that statically significant difference of resin cement; lowercase indicate that significant difference of time point

the tubular surface area.[31] It was observed that normal human teeth withstand temperatures between −7°C and 75°C without any damage to the pulpal tissue, but during the dental treatment, temperatures should not exceed 42°C.[32] Zach and Cohen[9] reported that minimum rise of 5.5°C intrapulpal temperature even induced necrosis. In addition, Hussey *et al.*[31] concluded that the pulp may be damaged by a temperature rise of 5.4°C ± 2.5°C during composite polymerization. However, Baldissara *et al.*[11] found that an average increase of 11.2°C did not affect the pulp.

Pohto and Scheinin[10] reported that the pulp is affected at temperatures ranging from 39°C to 42°C. Temperatures within this range lead to an increase in the blood flow of living rats. They also noted that when the duration of the thermal irritation is 30 s and the temperature ranges from 46°C to 50°C, stasis and thrombosis develop in the exposed pulp leading to arrest of the circulation. This circulation arrest occurs in the unexposed pulp at temperatures ranging from 46°C to 60°C, and when the duration of the thermal irritation is 2 min, temperature at 46°C, the circulation arrest occurs in the unexposed pulp. It has also been reported that the exposure to temperatures >47°C for 1 min may be sufficient to kill osteoblasts and other host cells.[33] Given the range of results, temperature increases >7°C (approaching or exceeding the 42°C) may be the critical temperature increase threshold at which pulpal damage begins. However, the threshold is related to thickness of dentin, light intensity, light unit type, exposure time, and dental restorative materials.[12-23,34] Therefore, to what extent the pulp can withstand a temperature increase before being damaged is not known.

In the present study, Pan F showed the highest temperature increase followed by Pan SA and RelyX in the 2nd and 4th time point. This result may be related to cementation procedure of Pan F, applying primer on tooth surface before light curing. The primer of Pan F contains self-etching agent used for pretreatment on the tooth surface. Pretreatment may change dentin surface to more sensitive for the thermal affect. In the other time points, the highest temperature increase was found in Pan SA group. This result may be related to a long self-curing polymerization process (12 min, 23°C/73°F). In addition, all cement groups showed no significant difference in the 14th and 16th min.

In the present study, the maximum temperature increase was observed in the Pan F group at the 2nd min (2.43°ΔC) and it is safe for normal pulp temperature. Because thermal irritation was lower than 5.5°C and short term, this temperature increase may not stimulate pulp damage. In addition, the RelyX group had the lowest temperature increase values. This difference may be due to the different degrees of conversion rate of resin or variable proportions of the resin matrix. A study of Al-Qudah *et al.*[35] concludes that the resin materials which have greater resin filler content may cause lesser temperature increase.

A pretreatment process is applied to the dentin surface before the application of the self-etch or total-etch resin cement. This pretreatment process consumes time and requires technical precision. The use of self-adhesive cement becomes popular since they do not require any operation on the dentinal surface before cementation.

Acid-etching, primer, and bond application steps have been eliminated in self-adhesive resin cement so as to make cementation faster and easier. Adhesive property of self-adhesive cement is associated with an acidic property of methacrylate monomer in its structure. This monomer provides demineralization and micromechanical retention through infiltration to dentin structure.[36]

Light unit type may affect pulpal health. Several researchers have reported that light-emitting diode light units caused lower temperature changes compared to plasma arch and quartz-tungsten-halogen light units.[15,17,18,37-39] Although the temperature increases detected from the polymerization and light units were not hazardous for pulpal health,[33,34] the light-emitting diode unit was used in the present study.

Limitations of this study are as follows: only one light unit and three resin cement were tested and all measurements were performed at a constant temperature of 23°C ± 2°C. Further studies should investigate the temperature changes of the different brands of resin cement at normal pulp temperature (34°C–35°C). In addition, laboratory and clinical studies are required to determine the critical temperature threshold at which pulpal damage begins.

CONCLUSIONS

Clinical significance

A comparison of temperature changes in the pulp chamber, using two-type (self-etch and self-adhesive) three different resin cement, showed an increase in temperature during the polymerization process. However, Pan F, Pan SA, and RelyX resin cement were within the safety limit because of short-term and lower than 5.5°C thermal irritation.

Within the limitations, the present study concluded that:

- Pan SA self-adhesive resin cement exhibited higher temperature increases than Pan F self-etch adhesive and RelyX self-adhesive resin cement
- A significant difference was observed among the time points and the highest temperature increases in the initial minutes. In the 2nd and 4th min, Pan F showed the highest temperature increase followed by Pan SA and RelyX. In the other time points, the highest temperature increase was found in Pan SA and no significant difference was observed in the 14th and 16th min.

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Conflicts of interest

There are no conflicts of interest.

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