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Original Paper

An investigation of thermal changes of various permanent dental cements

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The aim of this study was to investigate and compare the temperature rises which occurred during the setting reactions of different permanent cements used to lute fixed partial prosthodontics.

In this study, four cements were used. They were mixed in three different proportions: according to manufacturers' recommendations, at doubled powder ratio, and at doubled liquid ratio. With a thermocouple, the temperature rises which occurred during the setting reactions were measured. For each proportion, the measurement was repeated five times such that a total of 60 measurements were done for the four different cements. Data were analyzed using analysis of variance (ANOVA).

ANOVA results showed that cement type and the interaction between cement type and the powder-liquid ratio were statistically significant factors ($p<0.001$). Similarly, the powder-liquid ratio was a statistically significant ($p<0.01$) factor.

Among the dental cements tested, zinc phosphate cement showed the highest temperature rise during setting reaction, whereas glass ionomer cement showed the lowest.

Keywords: Permanent cements, Temperature change, Time

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INTRODUCTION

Dental cements are widely used for a variety of purposes in dentistry. This means that the mechanical[1,2], physical, and chemical features of a dental cement play a vital role in determining its suitability for a particular purpose. Moreover, it is of paramount importance that these materials do not cause any irritant effect on the pulp when used in a desired situation[3-5].

Mixing the powder and liquid of a dental cement causes an exothermic reaction[6]. The temperature rise which occurs during the mixing of these materials then reaches the pulp chamber through the dentinal tubules, thereby causing an increase in the pulp chamber temperature[7-12].

Langeland and Langeland[13] stated that as a result of temperature rise in teeth, coagulation of proteins in dentin will occur. Further, according to Zach and Cohen[14], a 5.5°C increase in pulp chamber temperature can result in pulpal damage.

The effects of heat generated during the setting reactions of dental cements on pulp tissue have been investigated in numerous studies[8,15,16]. The aim of this study was to investigate and compare the temperature rises which occurred during the setting reactions of different permanent cements used to lute fixed partial prosthodontics.

MATERIALS AND METHODS

Materials used

Four dental cements were selected for investigation in this study. Table 1 lists the commercial names, contents, and manufacturers of these four dental cements.

Experimental groups

Each dental cement was divided into three experimental groups, whereby the temperature rise which occurred during each setting reaction was measured.

In the first experimental group, the powder-liquid ratio was as per the manufacturer's recommendation, *i.e.*, the normal mixing proportion. In the second experimental group, the liquid amount was twice its advised volume. In the third experimental group, the powder amount was twice its advised volume. Nonetheless, all cements were mixed according to the mixing times recommended by the manufacturers. Table 2 presents the powder-liquid ratio and mixing time for each cement type.

Temperature rise measurement

To measure the temperature rise during setting, the cements were mixed in the abovementioned proportions according to the three experimental groups. Polycarbonate molds (3 mm diameter and 3 mm height) prepared for the experiment were filled with a cement, and then the probe of the thermocouple (Testo 735-2, Testo AG, Germany) was lowered into the center of the mold for an adequate amount of time in order for the setting reaction to be completed. The temperature rise measurement performed in this way using the thermocouple for each proportion was repeated five times, such that a total of 60 measurements were acquired for the four dental cements.

For standardization of experiments, the mixing spatula and mixing glass were of a standardized temperature.

Statistical analysis
Analysis of variance (ANOVA) was used for statistical evaluation. Means and standard deviations were calculated, and Duncan's multiply comparison test was performed.

RESULTS

Temperature rise measurement
Table 3 lists the means and standard deviations of temperature rise which occurred during the setting reactions of the different dental cements at different mixing proportions.

When dental cements were prepared according to the powder-liquid ratios recommended by the manufacturers, the highest temperature rise was seen in zinc phosphate cement at 13.58°C. This was followed by silicophosphate cement at 4.98°C and polycarboxylate cement at 3.13°C. The lowest temperature rise occurred in glass ionomer cement at 2.54°C.

When the powder ratio was twice its advised volume, the highest temperature rise was seen in zinc phosphate cement at 10.92°C. This was followed

Table 1 Materials used in this study

Type of cement	Brand name	Lot number	Manufacturer
Zinc phosphate	Adhesor carbofine	1031331-4	Dental cernokostelecka, Praha
Silicophosphate	Harvardid	280	Richter and Hoffman Harvard Dental
Polycarboxylate	Durelon	146078	3M ESPE AG, Germany
Glass (ionomer) polyalkenoate	Meron	300138	Voco, Germany

Table 2 Powder-liquid ratios and mixing times of dental cements

Cement	Normal proportion	Increased powder ratio	Increased liquid ratio	Mixing Time
Zinc phosphate	2.50 g/1 ml	5.00 g/1 ml	2.50 g/2 ml	20 sec
Silicophosphate	2.10 g/1 ml	4.20 g/1 ml	2.10 g/2 ml	30 sec
Polycarboxylate	1.50 g/1 ml	3.00 g/1 ml	1.50 g/2 ml	30 sec
Glass (ionomer) polyalkenoate	1.25 g/1 ml	2.50 g/1 ml	1.25 g/2 ml	45 sec

Table 3 Mean and standard deviations of temperature rise during the setting of dental cements

Cement	Normal proportion		Increased powder ratio		Increased liquid ratio	
	Mean	SD	Mean	SD	Mean	SD
Polycarboxylate	3.13	0.11	6.16	0.36	4.18	0.24
Zinc phosphate	13.58	0.66	10.92	0.30	13.80	0.27
Glass (ionomer) polyalkenoate	2.54	0.21	2.75	0.11	1.82	0.16
Silicophosphate	4.98	0.78	5.26	0.09	4.10	0.07

Table 4 Analysis of variance

Source	df	Sum of squares	Mean square	F
Cement	3	940.442	313.481	2510.557***
Powder-Liquid Ratio	2	1.018	0.509	4.076*
Cement × Powder-Liquid Ratio	6	54.450	9.075	72.678***
Error	48	5.994	0.125	

***: $p<0.001$
*: $p<0.01$

by polycarboxylate cement at 6.16°C and silicophosphate cement at 5.26°C. The lowest temperature rise occurred in glass ionomer cement at 2.75°C.

When the liquid ratio was twice its advised volume, the highest temperature rise was seen in zinc phosphate cement at 13.80°C. This was followed by polycarboxylate cement at 4.18°C and silicophosphate cement at 4.10°C. The lowest temperature rise occurred in glass ionomer cement at 1.82°C.

Statistical analysis

Table 4 shows the analysis of variance (ANOVA) results. ANOVA revealed that cement type and the interaction between cement type and powder-liquid ratio were statistically significant ($p<0.001$) factors. Similarly, the powder-liquid ratio was a statistically significant ($p<0.01$) factor.

Among the dental cements tested, the highest temperature rise was observed for zinc phosphate cement whereas the lowest for glass ionomer cement. According to Duncan's multiple comparison test, differences in cement type resulted in significantly different temperature rise values.

With regard to powder-liquid ratio, the differences were also statistically significant ($p<0.05$) when the liquid ratio was changed. When the liquid ratio was increased, the highest temperature rise was seen in zinc phosphate cement group; however, it was only a slight difference between the normal proportion group and the increased liquid ratio group. When the powder ratio was increased, it was again the zinc phosphate cement group which showed the highest temperature rise; however, the temperature rise was lower when compared to the normal proportion group. For polycarboxylate, silicophosphate, and glass ionomer cements, they registered their highest temperature rise values when the powder ratio was increased.

DISCUSSION

To date, numerous studies have investigated the temperature changes which occurred during the setting or polymerization reaction[4,5,17,18]. To measure temperature changes, thermocouple, computer-aided scanning calorimeter, variable thermal analysis, and infrared thermograph method have been employed in these studies[19,20]. In the present study, a K type thermocouple was used to measure the temperature rises of different dental cements during setting.

According to Akın[21], a temperature increase of 2–13°C was observed within approximately 13 minutes, and that the temperature decreased to its initial value within a very short time period. Indeed, the increase in temperature within such a short time period supported the assertion that pain occurred soon after the insertion of the restoration.

In this study, zinc phosphate cement exhibited a temperature rise of 13.58°C rise when it was prepared according to the manufacturer's recommendation. When the liquid amount was increased, the rise in the temperature was 13.80°C and it became 10.92°C when the amount of powder was increased. For all the mixing proportions, the zinc phosphate cement consistently exhibited the highest temperature rise values and that these values agreed with the upper limit of temperature rise obtained by Akın[21].

In a study by Klötzer *et al.*[15], the temperature rise for polycarboxylate cement ranged between 4 and 7°C, which was lower than that exhibited by zinc phosphate cement. In this study, the polycarboxylate cement exhibited a temperature rise of 3.13°C when it was prepared according to the manufacturer's recommendation. Temperature rise was 4.18°C when the liquid ratio was increased and it became 6.18°C when the powder ratio was increased. In other words, the results of this study agreed with the findings of Klötzer *et al.*[15] in that the polycarboxylate cement showed a lower temperature rise than the zinc phosphate cement. In another study, Walls *et al.*[16] investigated the factors influencing the setting reaction of glass ionomer cements. They reported a temperature rise of 1.93°C when glass ionomer cement samples were prepared in a normal mixing proportion. In this study, the glass ionomer cement samples showed lower exothermic temperature rises: temperature rise was 2.54°C when samples were prepared according to manufacturer's recommendation, 2.75°C when the powder ratio was increased, and 1.82°C when the liquid ratio was increased. With zinc phosphate cement, the highest temperature rise was observed when the liquid ratio was increased. On the other hand, with polycarboxylate, silicophosphate, and glass ionomer cements, they registered their highest temperature rise values when the powder ratio was increased. These variations in results might be attributed to the chemical reactions which took place when the powder and liquid were being mixed. Nonetheless, on the overall, it could be said that any change in powder-liquid ratio would lead to an increase in temperature. This meant that for polycarboxylate and silicophosphate cements, manufacturers' recommendations for powder-liquid ratios must be strictly adhered to. For glass ionomer cement, a lower temperature rise was observed when the liquid amount was reduced. However, it must be cautioned that any change in the powder-liquid ratio would affect the mechanical properties of the dental cement, resulting in a negative effect on crown retention. In light of the aforementioned concerns pertaining to temperature rise and compromised mechanical properties, dental cements should be prepared according to their manufacturers' recommendations.

Besides, different cement types have inherently different chemical compositions. This means that a change in the powder-liquid ratio would result in different effects being rendered. For example, with zinc phosphate cements, an increase in liquid ratio because of high acidity resulted in a higher temperature rise. On the other hand, when liquid ratio was increased for other cement types, the temperature rise during setting reaction was lower.

In the present study, zinc phosphate cement registered higher temperature increases during setting when compared to the other cements. Although the observed values could lead to irreversible changes in the pulp tissue, it should be pointed out that this amount of temperature rise is not directly transferred to the pulp chamber, and hence would not effectively result in irreversible changes. Based on the results of this study, zinc phosphate cement should not be the first choice as a luting agent; otherwise, apart from adequate thermal insulation, it is also advisable to increase the powder ratio as it led to a lower temperature rise during setting.

In a study by Plant *et al.*[8], zinc phosphate cement exhibited 2.14°C temperature rise during setting, whereas polycarboxylate cement exhibited only 0.40°C increase in temperature. Ulusoy and Denli[22] found that with 1 volume increase in the liquid ratio, zinc phosphate cement exhibited the highest temperature increase at 4.54°C followed by polycarboxylate cement at 2.1°C. The lowest temperature increase was exhibited by glass ionomer cement at 1.44°C. For the permanent cements used in this study, the highest temperature rise was seen in zinc phosphate cement at 13.58°C. This was followed by silicophosphate cement at 4.98°C and polycarboxylate cement at 3.13°C. The lowest temperature rise occurred in glass ionomer cement at 2.54°C. When the powder ratio was increased, the highest temperature rise was seen in zinc phosphate cement at 10.92°C. This was followed by polycarboxylate cement at 6.16°C and silicophosphate cement at 5.26°C. The lowest temperature rise occurred in glass ionomer cement at 2.75°C. When the liquid ratio was increased, the highest temperature rise was seen in zinc phosphate cement at 13.80°C. This was followed by polycarboxylate cement at 4.18°C and silicophosphate cement at 4.10°C. The lowest temperature rise occurred in glass ionomer cement at 1.82°C.

In this study, the results for zinc phosphate cement samples were much higher than the results of Ulusoy and Denli[22]. The differences could be attributed to differences in experimental design: Ulusoy and Denli measured the temperature rise transferred to the pulp chamber, whereas the temperature rise which occurred during setting was directly measured in this study. In a subsequent study, we shall evaluate the temperature rise transferred to the pulp chamber.

The temperature increase arising from the setting reaction of a dental cement occurs within a short time period, and at the end of this period the temperature returns to its initial value. Although other cements showed lower setting temperatures than zinc phosphate cement and which might not be enough to result in irreversible changes in the pulp tissue, the incidence of pain in patients after restoration placement seems to be typical due to the setting temperature of cements. Nonetheless, to keep the pain to a minimum, it is important to abide by the mixing rules and mixing proportions as recommended by the manufacturers.

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