In vitro pulp chamber temperature rise during fabrication of provisional restorations on different types of teeth

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Purpose: This in vitro study compared the temperature rise in the pulp chamber during fabrication of provisional resinous restorations on three types of teeth by a direct method.
Materials and Methods: The tip of a thermocouple was positioned into the pulp chamber of thirty intact extracted human teeth. Then the teeth were divided into three different tooth groups (incisor, premolar, molar) and prepared for a complete crown. One poly(methyl methacrylate) (Quick Resin) and two composites (Protemp 3 Garant and Luxatemp) were measured and mixed according to manufacturer's instructions. The resin mixture was placed into a poly(vinyl siloxane) impression and was then positioned on the prepared teeth. Temperature change in the pulp chamber during polymerization of the resin mixture was recorded. The results were analyzed with a two-way ANOVA and the LSD test ($\alpha=0.05$).
Results: Two-way ANOVA revealed that intrapulpal temperature changes were significantly influenced by tooth types ($p<0.01$) and provisional resinous materials tested ($p<0.01$), but no significant interaction between the tooth types and the tested materials ($p=0.575$) was observed. LSD test revealed that the intrapulpal temperature rise was higher when provisional resinous materials were fabricated on incisors than on premolars ($p<0.01$) or on molars ($p<0.01$).
Conclusion: Within the limitations of this in vitro study, the results indicate that the poly(methyl methacrylate) produced the higher exothermic reaction than the composite resins. Fabrication of provisional restorations directly on incisors could induce higher temperature rise than on premolars or on molars.
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Key Words: intrapulpal temperature rise, provisional restoration, thermocouple.

Introduction

Provisional restorations are an essential part of fixed prosthodontic treatment. Their purposes are to provide stabilization of occlusion, protection of the teeth and the periodontal tissues, function, esthetic enhancement, and provision of diagnostic information.[1-2] Patients must be provided with a provisional restoration from initial tooth preparation until the definitive prosthesis is placed. When fabricating provisional resinous restorations using a direct method, clinicians have to face two major problems. The first problem results from the presence of uncured free monomer, which can be harmful to the pulp, especially when placed in direct contact with newly cut dentinal tubules.[3] Secondly, most of provisional resinous materials generate exothermic polymerization reaction, which can cause a temperature rise in the pulp chamber. This temperature rise may injure the dental pulp.[4-7] In general, temperature increases more than 5.5˚C in the pulp lead to considerable damage, resulting in 15% of the pulps tested to lose vitality, according to Zach and Cohen.[8]

Previous in vitro studies have compared intrapulpal temperature rise during fabrication of provisional resinous restorations.[4,7,9] These results suggested the possibility of thermal damage to dental pulp and odontoblasts during the setting of provisional resins. Moulding and Teplitsky[10] suggested that intrapulpal temperature rise during polymerization of provisional resinous materials were dependent on the type of provisional resin, and the type of matrix used to retain the material on the tooth during polymerization. The poly(methyl methacrylate) (PMMA) resin produced significantly higher temperature rise than did for poly(vinylethyl methacrylate) (PVEMA), visible-light-polymerizing urethane dimethacrylate (UDMA) composite, and bis-GMA composite, with the UDMA exhibiting significantly less polymerization temperature rise than the other resins.[6,11] When provisional resins were used in combination with matrix made from siloxane and irreversible hydrocolloid materials, the intrapulpal temperature rise could be reduced.[7,10,11] The aim of this in vitro study was to compare the temperature changes in the pulpal chamber during fabrication of provisional resinous crowns on different types of teeth using a direct method.

Materials and Methods

A PMMA resin (Quick Resin) and two bis-GMA composites (Protemp 3 Garant and Luxatemp) were evaluated in this study (Table 1).

Table 1. Provisional resinous materials.

Trade name	Material type	Manufacturer	Lot number
Quick Resin	MMA-PMMA	Shofu Inc., Kyoto, Japan	Power, 060409; Liquid, 060517
Luxatemp	Bis-GMA composite	DMG, Hamburg, Germany	Base, 534515; Catalyst, 560401
Protemp 3 Garant	Bis-GMA composite	3M ESPE, Seefeld, Germany	Base, 227117; Catalyst, 223201

The methodology applied in this study was authorized by the Ethics Committee of the Fourth Military Medical University. Thirty intact, freshly extracted human teeth were used in this study. The teeth were separated into three groups of 10 teeth each. To evaluate temperature changes in teeth with different dentin thickness and different tooth structure, three different types of human teeth were selected (10 teeth of each type, i.e., maxillary incisors, maxillary premolars, and mandibular molars). In each group, teeth of homogeneous size and shape were selected to provide similar hard tissue structure and ensure equal distances from the pulp to the surface of the tooth.

All the thirty teeth were sectioned with a cutting disk approximately 2 mm below the cementoenamel junction perpendicular to the long axis of the teeth. The opening into the pulpal chamber from the radicular portions of the teeth was enlarged as needed to insert the thermocouple wire. The pulpal chambers were cleaned of remnant pulp tissues with a spoon excavator and sodium hypochlorite application for 1 minute. The pulp chambers of the teeth were rinsed with distilled water and air-dried. A J-type thermocouple wire (Omega Engineering Inc., Stamford, CT, USA) was insert into the pulpal chamber, touching the roof of the chamber. Silicone transfer compound (Philips ECG Inc., Waltham, MA, USA) was then injected into the pulp chamber, surrounding and stabilizing the thermocouple in position. This compound facilitated the transfer of heat from the walls of the pulp chamber to the thermocouple. Before temperature measurements were made, radiographs were made of the teeth to ensure that tips of the thermocouples were in contact with the roofs of the chambers. After that, root stubs of the teeth were secured to acrylic resin bases with an auto-polymerizing resin (Unifast LC; GC America, Alsip, IL, USA). After complete polymerization of the acrylic resin, a polyether impression material (Impregum, 3M ESPE, Seefeld, Germany) of the tooth/resin base assembly was made using a custom tray. All the teeth were then prepared for a metal-ceramic complete crown with a 1.5 mm shoulder, and the occlusal reduction was 2.0 mm. The acrylic resin base/prepared tooth/engaged thermocouple assembly was then submerged in a water bath (Water Bath; Whip Mix Corp., Louisville, KY, USA) containing distilled water at a temperature of 37˚C. The tooth was preheated and allowed to thermally equilibrate. The water bath was used to simulate intraoral conditions.

The provisional resinous materials tested were measured and mixed according to the manufacturer's instructions. For Quick Resin material, the ratio of the powder-liquid was standardized on a precision scale: 1 g of powder and 0.5 g of liquid were mixed in a disposable cup with a clean plastic spatula for 15 s. For Protemp 3 Garant and Luxatemp, the paste-to-paste ratios were mixed automatically proportioned with a special auto-mix gun applicator provided by their manufacturers. The poly(vinyl siloxane) impression matrix was full-filled with the mixed resinous materials and then positioned on the prepared tooth preparation. All excess resinous materials were removed from the margins of the tooth by the use of an explorer. The J-type thermocouple wire was connected to a digital precision thermometer (XSTC, Beijing Kunlun Tianchen Instrument Technology Co., Beijing, P. R. China). The temperature rise in the pulpal chamber was recorded every 2 s over a 10-minute period using the digital thermometer which read in 0.1˚C increments. Calibration of the thermometer was not required. Specification accuracy was maintained without user adjustment. The collected data were monitored in real time and stored in its memory before the data were transferred to the computer. After complete polymerization of the resinous material, the matrix was removed from the tooth, and the provisional crown was retrieved. Each material was tested 10 times.

For each group, the temperature variation (ΔT) was determined as the increase from baseline temperature to the highest temperature recorded during the polymerization of resinous materials. Ten calculated temperature changes were averaged to determine the mean values in temperature rise. A temperature increase of less than 5.5˚C was considered favorable and set as the baseline according to Zach and Cohen.[8] The values of each group were compared by two-way analysis of variance (ANOVA). The two factors analyzed were provisional resinous material and tooth type. After the two-way ANOVA, the least significant difference tests (LSD test) were performed for comparisons among groups at the 0.05 level of significance.

Results

Table 2 presents the descriptive statistics results, including the mean, standard deviation, minimum and maximum values, and comparisons for tooth types and different provisional materials.

Table 2. The descriptive statistic values of intrapulpal temperature changes during polymerization of provisional materials on different types of teeth[a]

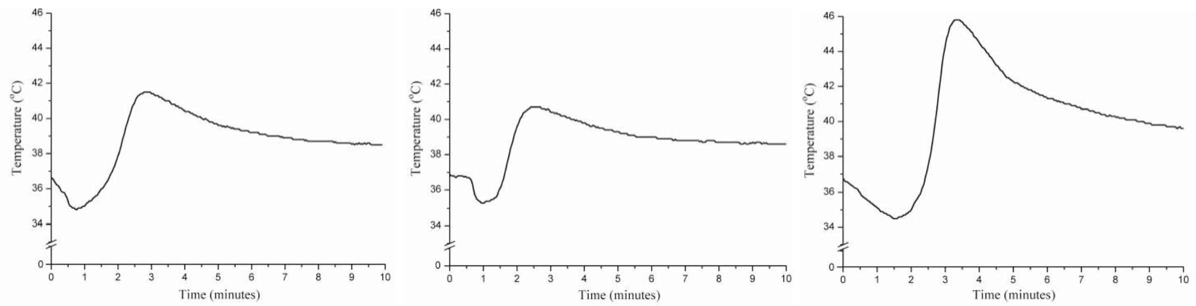
Group	Tooth type	Provisonal materials	Sample size	Temperature				Test[b]	P-value
				ΔT	SD	Minimum	Maximum		
1	Incisor	Luxatemp	10	4.27	0.25	3.9	4.6	A	
2	Incisor	Protemp 3 Garant	10	4.33	0.41	3.6	4.8	A	
3	Incisor	Quick Resin	10	10.84	0.87	9.8	12.1	C	
4	Premolar	Luxatemp	10	3.90	0.35	3.2	4.4	A	
5	Premolar	Protemp 3 Garant	10	3.87	0.39	3.1	4.5	A	P<0.05
6	Premolar	Quick Resin	10	9.95	0.82	8.7	11.4	B	
7	Molar	Luxatemp	10	3.90	0.19	3.6	4.2	A	
8	Molar	Protemp 3 Garant	10	4.01	0.26	3.6	4.4	A	
9	Molar	Quick Resin	10	10.09	0.91	8.9	11.5	B	

a, ΔT indicates mean difference between maximum and minimum temperature values; SD, standard deviation;
b, Group with different letters are significantly different from each other.

For incisors, the average temperature rise in the pulp chamber ranged from 4.27˚C (Luxatemp, Group 1) to 10.84˚C (Quick Resin, Group 3). For premolars, temperature rise ranged from 3.87˚C (Protemp 3 Garant, Group 5) to 9.95˚C (Quick Resin, Group 6). For molars, temperature increases ranged from 3.90˚C (Luxatemp, Group 7) to 10.09˚C (QuickResin, Group 9).

According to two-way ANOVA, temperature rise in the pulp chamber varied significantly depending on the different tooth types ($p<0.01$) and different provisional materials ($p<0.01$). ANOVA revealed no significant differences for combination of tooth types and provisional materials ($p=0.575$). LSD test revealed statistically significant differences among the groups ($p<0.05$). Quick Resin induced much higher intrapulpal temperature rise than Protemp 3 Garant and Luxatemp did. However, there were no statistically significant differences between Protemp 3 Garant and Luxatemp (Table 2).

When Quick Resin was used on maxillary incisors (Group 3), the temperature rise in the pulp chamber was statistically significantly higher than it used on maxillary premolars (Group 6) and mandibular molars (Group 9). This phenomenon did not happened to Protemp 3 Garant and Luxatemp. Although the temperature rise of the two bis-GMA composites used on maxillary premolars was higher than they used on maxillary premolars and mandibular molars, the differences were not statistically significant. The temperature rise plotted against time is depicted in Fig. 1 for each material tested. A sudden decrease in temperature was measured when the preheated tooth came in contact with the cold, freshly mixed resin within the poly(vinyl siloxane) matrix.



a b c

Fig. 1. Temperature rise versus time of three provisional materials tested. Note initial decrease in temperature caused by contact with cold mixed resin. a, Luxatemp; b, Protemp 3 Garant; and c, Quick Resin.

Discussion

The thermal effect during the polymerization of provisional resinous materials is well known. A few of studies revealed temperature changes in pulpal chamber were affected by several factors including material types[6,11] and matrix types.[7,10,11] In this in vitro study the heat generated during the fabrication of provisional resinous crowns on different tooth types using a direct method were measured. Under the conditions of the present study, the PMMA resin produced much more intrapulpal temperature rise than the other two bis-GMA composite resins on all the three types of teeth. Also, the temperature rise in pulpal chamber differed among the three types of teeth. When provisional materials were used on maxillary incisors, the temperature rise in the pulp chamber was higher than those used on maxillary premolars and mandibular molars. However, the differences were statistically significant only with Quick Resin ($p<0.05$). As far as Luxatemp and Protemp 3 Garant were concerned, the differences were not statistically significant ($p>0.05$) (Table 2). These findings were in accordance with the previous results.[12,13]

For the present comparative study, extracted adult incisors, premolars, and molars were selected to assess the thermal changes in different tooth groups with different dentin thickness and dentin structure.[14] Teeth with abnormally large or small pulp chambers were excluded from the study. This procedure was followed by elimination of any possible structural variables of teeth that may manifest as differences in the thermal conductivity and specific heat. However, even after stringent selection, teeth exhibited some differences in tooth morphology, dentin structure and thickness. This may explain the temperature differences between the teeth tested in the same group.[15,16] On the other hand, the teeth used in this study were collected from an adult sample, so the thermal conduction to the pulp chamber during polymerization procedures might have been limited compared with the clinic situation. Therefore, one would expect to record higher temperature increases when younger teeth are used for a similar study.

The remaining dentin thickness and its poor thermal conductivity was the critical factors in reducing the intrapulpal temperature rise for the present study.[16] The thermal effect on the pulp tissue depends on the variations in the dentin thickness of the pulp chamber.[17] The incisors exhibit a higher risk of thermal damage because of thinner dentin thickness on the labial side.[12] Uzel et al.[18] investigate the temperature changes in the pulp chamber during bracket bonding using different light sources. They found that all light sources produced higher intrapulpal temperature rise in the incisor than in the premolar. Other researchers also considered the comparison of tooth types.[12,13] Unfortunately, to the best of our knowledge, there is no paper in the open literature dealing with the effect of tooth types on the temperature changes in the pulp chamber during the polymerization of provisional resinous materials.

Thus, 30 teeth selected stringently were divided into three tooth types of 10 teeth each in the present study. Though the teeth in the same group exhibited some differences in remaining dentin thickness, the standard deviation for temperature rise in same tooth type group was small compared to the mean value. This is probably due to the fact that the dentin thickness was positive correlation with tooth size.[19] After all the teeth were prepared to gain a same size shoulder with 1.5mm thickness, the remaining dentin thickness of relatively bigger tooth was larger than that of relatively smaller tooth. Simultaneously, the quantity of the provisional resinous material used in relatively bigger tooth was also larger than that used in relatively smaller tooth. Tjan et al.[9] indicated that the flow of heat through the dentin was inversely proportional to the remaining dentin thickness and directly proportional to the amount of material used. Thus the quantity of heat flowing through the dentin barrier to the pulp chamber of the same group tended to be equal during the setting of the same material.

Zach and Cohen[8] demonstrated that a 5.5˚C intrapulpal temperature rise led to necrosis of the pulp in 15% of teeth, an 11.1˚C rise resulted in necrosis of the pulp in 60% of teeth, and a 16.6˚C rise led to necrosis of the pulp in 100% of teeth. These results as well as the findings of Pohto and Scheinin[20] indicate that the critical temperature for irreversible damage to the pulp begins at 42-42.58˚C. The temperature rise resulting from the polymerization process of the Quick Resin material ranged between 8.7˚C and 12.1˚C. Considering these crucial values, the intrapulpal temperature rise detected in Quick Resin groups must be viewed as dangerous. Careful management should be required when using PMMA resin like Quick Resin for fabrication of provisional restoration by the direct method.

It should be noted that this is an in vitro study and, like other in vitro studies, has some limitations. The experimental design of the present study did not consider the effect of blood circulation in the pulp chamber and fluid motion in the dentinal tubules and surrounding periodontal tissues on promoting heat conduction in vivo, limiting intrapulpal temperature rise. Further in vivo animal studies are necessary to verify the results of the present study.

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