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Original Article

Comparison of temperature rise in pulp chamber during polymerization of materials used for direct fabrication of provisional restorations: An *in-vitro* study

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ABSTRACT

Objective: The purpose is to compare temperature rise in the pulp chamber during fabrication of provisional crowns using different materials and on different types of teeth using direct technique. **Materials and Methods:** An extracted, sound, caries free maxillary central incisor and a mandibular molar were selected for the study and crown preparations of all ceramic and all metal were done on central incisor and mandibular molar, respectively. Materials tested were DPI tooth molding self-curing material and protemp-4. Addition silicone putty was used as a matrix and 80 provisional crowns were fabricated, of which 40 were on central incisor and 40 on mandibular molar. Depending on the type of material used, they were further divided into two subgroups: Each comprising 20 provisional crowns. Temperature readings were recorded using K type of thermocouple with 0.1°C precision digital thermometer. **Statistical Analysis Used**: Analysis of variance, Tukey honest significant difference and Kruskall–Wallis H-test. **Results:** Statistically significant difference exists between two materials tested on the basis of peak temperature achieved and time taken by a particular material to reach peak temperature. Peak temperature achieved was highest for provisional crowns with DPI tooth molding self-curing material on maxillary central incisor (40.39 + 0.46), followed by DPI tooth molding self-curing material on mandibular molar (40.03 + 0.32), protemp-4 on maxillary central incisor (39.46 + 0.26) and least with protemp-4 on mandibular molar (39.09 + 0.33). The time taken to reach peak temperature was almost double in DPI tooth molding self-curing material (5 min) than in protemp-4. **Conclusion:** Polymethyl methacrylate resin produced higher intra-pulpal rise when compared to newer generation bis-acrylic composite.

Key words: Bis-acrylic composite resin, exothermic heat, polymethyl methacrylate resin, provisional restorations

INTRODUCTION

A desire to have a pleasing appearance is the necessity of today. However, with age, the person starts losing his teeth either due to numerous periodontal, restorative problems or due to the traumatic injuries caused, making a person orally crippled,[1] which can best be restored with the help of fixed prosthesis.

During tooth structure preparation in fixed prosthetic treatment, oral tissues are inadvertently injured ranging from mild reversible damage to pulpal death. Various authors have addressed biological variables encountered in complete crown preparation. Robinson *et al*.[2] stated that approximately 1–2 million dentinal tubules are exposed during an average tooth preparation of a posterior crown, which may lead

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to severe sensitivity to the patients or even death of pulpal tissue.

Providing provisional crowns to patients help us to evaluate the entire range of requirements, which a person desires from definitive prosthesis with the exception of longevity and sophistication of color.[3] Though, Provisional restorations ensures fulfillment of entire range of mechanical, biological and esthetic requirements, their fabrication should be done with care, since, the materials and methods used may be detrimental to the vitality of the pulp.

The fabrication of the provisional restorations using direct technique presents two major problems namely presence of free residual monomer, which may cause soft tissue lesions,[4] allergic stomatitis[5] when in contact with the oral mucosa and the exothermic heat released during polymerization of the materials. This exothermic heat released is a major biological threat because a previous histological study by Zach and Cohen[6] stated a thermal rise of 10°F is sufficient to cause irreversible damage to pulpal tissues. Driscoll *et al*.[7] studied exothermic heat released by materials tested and stated them to be potent cause of thermal injury for teeth. Thus, it seems that a material having less or no exothermic heat release should be preferred to preserve the vitality of the pulp.

The purpose of this *in vitro* study is to compare temperature rise in the pulp chamber during fabrication of provisional crowns using different materials and on different types of teeth using direct technique.

The null hypothesis is that no difference exists between the two materials tested on the basis of the exothermic heat released.

MATERIALS AND METHODS

A polymethyl methacrylate (PMMA) resin (DPI tooth molding material) and a new generation bis-glycidyl methacrylate (GMA) resin (Protemp-4) were selected for the comparison on the basis of exothermic heat release. The reason for their selection as test materials were their wide spread use in clinical practice [Table 1].

An intact, caries free mandibular molar and a central incisor were freshly extracted and stored in 10% formaldehyde in 100 ml of water for 1 h. The thickness of both the teeth was determined mesio-distally using Vernier caliper and was found to be 8.5 mm for the incisor and 10 mm for the molar. Root portions were sectioned with the carbide disc at the furcation level for the molar and 2 mm below the CEJ for central incisor. An opening was made into the pulp chamber from the radicular portion to clean the organic remnants of pulpal tissue with 5.25% sodium hypochlorite and distilled water. The opening was closed with cotton pellet and two boxes of 6 cm × 4 cm were prepared using heat cured resin. A through and through hole was drilled in both the boxes in the center and the teeth were stabilized in position with the help of sticky wax. Cotton pellets were removed from the apical openings in both the assemblies and K type of thermocouples was inserted into the pulp chamber, touching the roof of both the chambers. Amalgam was injected into the pulp chamber, surrounding and stabilizing the thermocouples in position, which were connected to the high precision thermometer of 0.1°C [Figure 1]. Radiographs were carried out to confirm the position of thermocouples [Figure 2]. The amalgam inside the pulp chamber served the dual purpose of stabilization of the thermocouple inside pulp chamber and as a medium for transferring the thermal energy because amalgam is a good conductor of heat and will transfer the thermal heat from all the directions to the thermocouple.

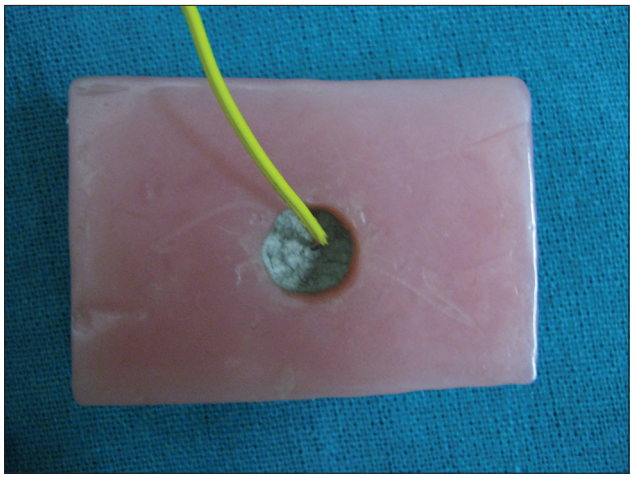

Figure 1: Amalgam with thermocouple inserted in hollow pulp chamber

Table 1: Resin materials included in the study

Brand	Material type	Manufacturer	Batch number
DPI self-cure tooth molding powder	Poly methyl methacrylate	Dental products of India, Mumbai, India	Powder-12101
RR liquid		Dentsply India Pvt. Ltd, Gurgaun, India	Liquid-RL101012
Protemp-4	Bis-acrylic composite	3M ESPE, St. Paul, Minnesota, USA	502053

Impressions of both the teeth assemblies were made with polyvinyl siloxane (PVS) putty consistency using custom trays made of barrels of syringe, each of 3 ml in length which served the purpose of matrix [Figure 3]. Maxillary central incisor was prepared for an all ceramic preparation with 1.5 mm shoulder and 2 mm incisal reduction and mandibular first molar for an all metal preparation with 0.5–0.8 mm chamfer finish line and 1.5 mm occlusal reduction on functional and 1 mm on nonfunctional cusps [Figure 4].

A thin layer of petroleum jelly was applied to the tooth and the resin block and entire assembly was placed in a water bath at a constant temperature of 37°C to thermally equilibrate. The water bath was used to simulate intraoral conditions.

For DPI tooth molding provisional crowns, powder and liquid were weighed on electronic scale and mixed as per manufacturer's instructions. For the bis-GMA acrylic composite crowns, an automated calibrated syringe provided by the manufacturer was used. The materials to be tested were loaded in the prepared matrices of syringes and placed on the prepared teeth. All the excess resin was removed using explorer. Temperature was recorded using digital thermometer during polymerization of resins at 30 s interval for a period of 15 min until no further rise in temperature was noted. A total of 80 provisional crowns were fabricated of both the materials on both the test assemblies and divided into four subgroups of 20 each [Table 2]. Since, all the materials and assemblies were at 37°C initially; any rise in temperature was attributed to the heat of polymerization transmitted through the dentin to pulp chamber containing silver amalgam and thermocouple. Intrapulpal temperature differences were recorded and data was statistically analyzed using analysis of variance (ANOVA), Tukey honest significant difference and Krukall–wallis H-test.

RESULTS

The descriptive statistics for the mean temperature rise values were carried out taking in consideration both the variables individually as well as in association to each other. The comparison of both the groups depending on the type of teeth, irrespective of the type of material used states higher mean temperature recorded in incisor (39.50°C) than that recorded in molar (39.17°C) [Figure 5]. The mean temperature rise calculated on the basis of material used without taking in consideration the type of teeth used depicts the higher mean temperature values in PMMA (40.04°C) than in bis-GMA composite resin (39.16°C). The results for the mean temperature rise values of the

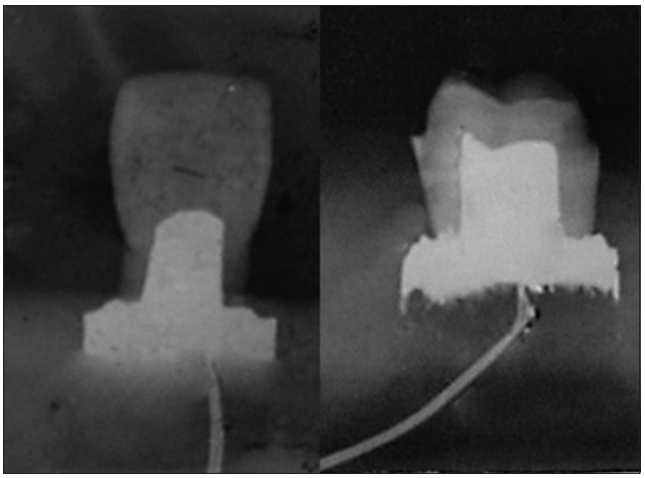

Figure 2: Radiographic confirmation of thermocouple in incisor and molar

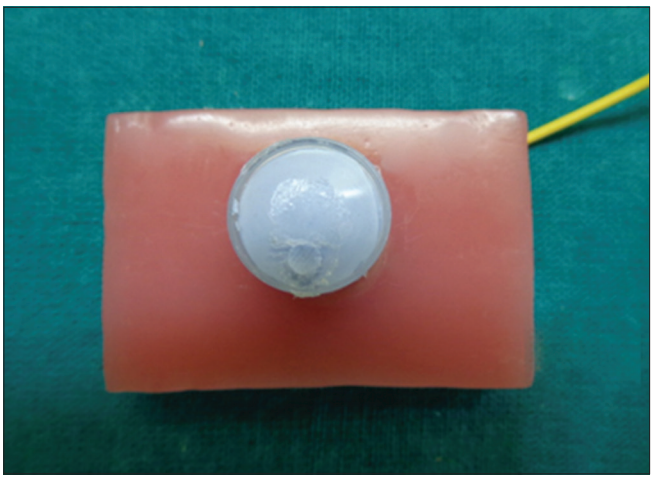

Figure 3: Fabrication of polyvinyl siloxane matrix using syringe

Figure 4: Teeth prepared with finish lines

Table 2: Distribution of samples showing experimental set up

Group	Type of provisional fabricated crowns	Total number of samples	Subgroups (materials used)	
			(a) Poly-methylmeth acralate	(b) Bis-acrylic composite
I	Molar	40	20	20
II	Incisor	40	20	20

resin materials included in the study on different types of teeth are depicted in [Figure 6]**.** Mean temperature rise for provisional crown fabrication ranged from 39.09°C for group Ib to 40.39°C for group IIa, which was statistically significant ($P < 0.001$).

The median time taken to achieve peak temperature was 2.5 min for subgroups Ib and IIb while, in subgroup Ia and IIa, it was 5 min. The difference in time taken to achieve peak temperature is statistically significant ($P < 0.001$).

Multi-variant model assessment was also carried out in the present study. Variability is assessed for two types of materials (PMMA resin and bis-GMA composite resin) and two types of teeth (molar and incisor) using Two-way ANOVA. It was found that maximum temperature change was considered as a dependent variable on the individual variables, resin materials and type of teeth. The model was having good explanatory capability ($R^2 = 0.672$) depicting model to be acceptable [Table 3].

DISCUSSION

This *in vitro* study demonstrated that PMMA resin when used on incisor produced highest exothermic reaction of the materials tested. Null hypothesis that no difference exists between the two materials when compared for exothermic heat released was rejected as statistically significant difference of 1°C exists between the two materials when tested for mean peak temperature. Throughout the study procedure, both the materials tested showed a rising trend in temperature with increase in time and a regressive trend after achievement of peak temperature, with almost returning to baseline temperature at end of 15 min [Figure 7]. The reason for this characteristic trend was due to the release of exothermic heat during polymerization of both the materials tested. Both PMMA and bis-acrylic resins release exothermic heat as they polymerize by addition polymerization mechanism in which monomers add sequentially to the end of a growing chain.[8] In both the resins, there is exothermic conversion of vinyl groups containing carbon carbon double bonds to carbon carbon single bonds. The amount

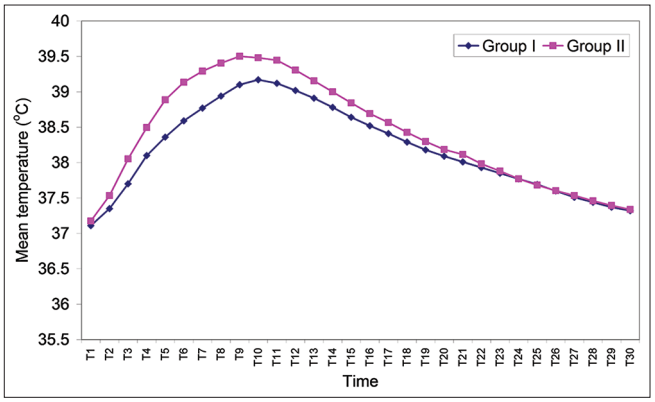

Figure 5: Temperature reading in two groups irrespective of material used

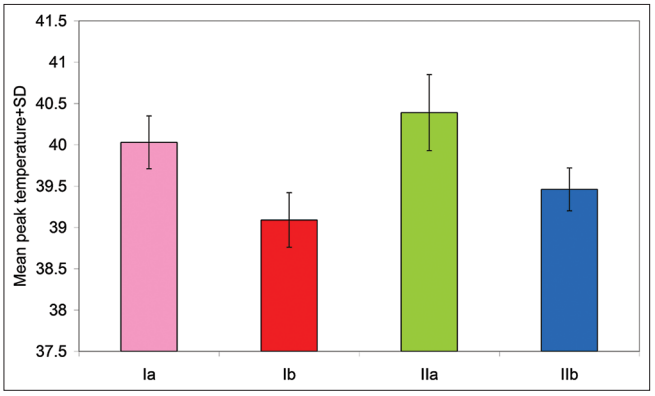

Figure 6: Mean peak temperature at different time intervals in two subgroups of groups I and II

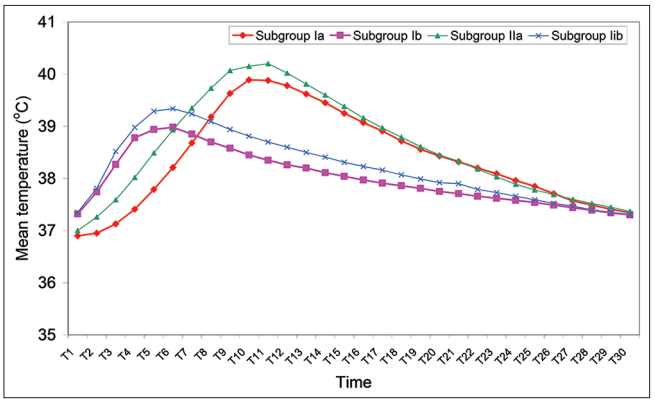

Figure 7: Characteristic pattern by both the sub groups of group I and II

of exothermic heat released by resins increases with increased number of vinyl groups which is directly related to resin volume. Bis-acrylic composites have

Table 3: Two way analysis of variance to find out association of maximum temperature achieved with type of teeth and type of material

Source	Type III sum of squares	df	Mean square	*F*	Significant
Corrected model	20.223 (a)	3	6.741	54.916	<0.001
Intercept	126,341.408	1	126,341.408	1,029,257.906	<0.001
Material	17.485	1	17.485	142.440	<0.001
Teeth	2.738	1	2.738	22.305	<0.001
Material*teeth	0.000	1	0.000	0.004	0.949
Error	9.329	76	0.123		
Total	126,370.960	80			
Corrected total	29.552	79			

aR^2=0.684 (adjusted R^2=0.672)

found to have 55–75% less conversion than acrylic resins.[9,10]

For the uniformity of the parameters for the materials to be tested, two test assemblies, one having central incisor and the other having mandibular first molar were prepared with other influencing factors, that is, matrix type and thickness, residual dentin thickness and thermocouples constant for both the assemblies to avoid any error in temperature change recorded. Daronch *et al*.[11] and Oztürk *et al*.[12] compared different types of provisional restorative materials and found residual dentin thickness to be a critical factor in determination of intrapulpal temperature rise.

The entire study was carried out in water bath at 37°C simulating the intraoral conditions at 30 s interval for a period of 15 min with the aim of recording even minute deflections in temperature and both type of materials have most of the polymerization complete in 15 min. Only, differences were saliva, pulp and gingiva, which may provide slight damping effect of exothermic heat. Saliva was substituted by later of petroleum jelly, which also helped in easy retrieval of fabricated provisional crowns.

In intergroup comparison irrespective of material type, group II (incisors) showed higher mean values than group I (molars). Peak temperature achieved in group I was (39.17 ± 0.79) whereas in group II was (39.50 ± 0.82). This difference may be attributed to the type of preparation, which has led to decreased residual dentin thickness in incisors as compared in molars. Xie *et al*.[13] conducted similar type of study using incisors, premolars and molars with maximum values in incisors.

In intergroup comparison between different subgroups, the order of mean peak temperature rise in different subgroups was highest for IIa, followed by Ia, IIb and lowest by Ib. This can be explained as of increased exothermic reaction in case of PMMA, and in incisors, we have gone for an all ceramic preparation, stating reduced dentin thickness and increased volume of resin used as compared to molar. The results are in agreement with the study conducted by Vallititu,[14] which states that peak temperature rises with increased amount of resin used. The studies by Molding[15] and Michalakis *et al*.[16] illustrate PMMA has highest exotherm release than other materials tested which supports the present study.

Trowbridge *et al*.[17] stated the temperature of healthy normal dental pulp to be 34–35°C. Assuming 35°C to be the intrapulpal temperature, there is a rise of 4.46°C in protemp-4 and a rise of 5.39°C in DPI tooth moulding self-cure resin which is very close to the critical temperature of 5.6°C[6] for causing irreversible damage to pulpal tissues. Thus, the material preferred among the materials tested is protemp-4 for direct fabrication of provisional crowns.

Various suggestions such as use of condensation and addition silicones as putty matrices,[18] precooling of putty matrix and use of desensitizer has found to be effective in reduction of intrapulpal rise in temperature.[19] Akova *et al*.[20] and Usumez *et al*.[21] investigated the effects of different matrices and application of desensitizer on rise in temperature and found no effects of matrix and desensitizer on the temperature rise. The median time taken to reach peak temperature was same for both IIa and Ia that is 5 min and 2.5 min for IIb and Ib stating that protemp-4 has a faster fabrication time [Table 4].

Kim and Watts[22] conducted study comparing dimethacrylate and monomethacrylate materials and found dimethacrylate materials to be preferable to monomethacrylate materials as can reduce the fabrication time. However, the slower setting reaction is advantageous in exotherm terms. Hence, it can be suggested that a reformulation of dimethacrylate

Table 4: Median time taken to achieve peak temperature

Subgroup	Median time taken
Ia	5 min
Ib	2.5 min
IIa	5 min
IIb	2.5 min

χ^2=54.893 (df=3); *P*<0.001 (Kruskall-Wallis test)

based materials (Protemp 4); perhaps by reducing the concentration of initiator would produce a material with slightly slower setting and less production of exothermic heat.

Since, direct technique exposes the freshly prepared tooth surface to free residual monomer and exothermic heat during polymerization. To reduce this exposure, it is suggested to use dental varnish, dentin desensitizer or petroleum jelly prior to provisional crown fabrication.

Yondem *et al*.[23] conducted a study to evaluate the temperature rise during polymerization of resin composite by various light polymerization units and found the temperature rise much below the critical temperature of 5.5°C. Hence, light cure or dual cure composites can also be suggested as provisional crown materials. Malčić *et al*.[24] stated that care should be taken while using blue phase light-emitting diode light for polymerization of resins and suggested to use it at low power modes and with small duration of exposers.

We have considered the ideal preparations in our test specimens and petroleum jelly as separating medium which may have led to reduced transmission of heat as petroleum jelly is a bad conductor of heat. Blood flow of pulp, saliva and peridontium may also help in dissipation of exothermic heat *in vivo* conditions which is not taken in consideration in the study.

In case of metallic restorations, tilted and rotated teeth where we have to sacrifice increased amount of tooth structure, other influencing factors, that is, volume of the material to be used, remaining residual dentin thickness and type and thickness of matrix should be taken in consideration while opting for provisional crowns fabrication using direct technique.

Further, *in vivo*, long term studies can be carried out on these materials with precooling the matrix or use of air-water spray or dental varnish application which may further decrease the intrapulpal temperature rise.

Within the limitations of the study, we suggest that:

- Among the two materials tested, protemp-4 seems to be less harmful to the pulpal tissues than DPI tooth molding self-curing resin and can be used for direct fabrication of provisional crowns with PVS putty as matrix
- Polymethyl-methacrylate as a provisional restorative material should be avoided as of increased residual monomer content and increased chances of thermal trauma to pulpal tissues
- Whenever, there is a need to fabricate long span provisional restorations with multiple pontics, we should not shirk to spend some extra time and material and should prefer the indirect technique.

CONCLUSION

- The type of resin used during direct fabrication of provisional restorations affects the intrapulpal temperature rise. The PMMA self-curing resin produced a significantly higher exothermic heat release than the bis-acrylic composite resin included in the study
- Intrapulpal temperature rise depends on the type of teeth tested and the type of preparation which eventually varies the amount of residual dentin thickness and the volume of resin to be used during direct fabrication of provisional crowns
- Maximum intrapulpal temperature rise was found in provisional crowns fabricated of PMMA resin on incisor and minimum with protemp-4 on molar
- Protemp-4 is found to have less time to reach peak temperature when compared to DPI tooth molding self-cure resin thus stating shorter fabrication time.

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