ORIGINAL RESEARCH

Effect of Three Different Cooling and Insulation Techniques on Pulp Chamber Temperature during Direct Temporization with Polymethyl methacrylate-based Resin

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ABSTRACT

Aim and objective: This in vitro study evaluates and compares the changes in pulp chamber temperature during direct fabrication of provisional restorations in maxillary central incisors after using three different cooling techniques.

Materials and methods: Total of 60 samples of maxillary central incisors along with their putty indices were divided into four groups (one control and three experimental) and were prepared using a surveyor cum milling machine. Teeth were sectioned 2 mm below cementoenamel junction and a K-type thermocouple wire was inserted in the tooth and secured at the pulpal roof using amalgam. Putty index filled with DPI tooth molding resin material (polymethyl methacrylate (PMMA)) was placed on the tooth and temperature changes per 5 seconds were recorded by temperature indicating device for the control, on–off, precooled putty, and dentin bonding agent (DBA) group.

Results: The highest mean obtained was of the control (11.04°C), followed by DBA group (9.53°C), precooled putty group (6.67°C), and on–off group (1.94°C). Precooled putty index group took maximum time to reach the baseline temperature (847.5 seconds).

Conclusion: On–off technique is the most effective method to reduce the intrapulpal temperature during polymerization, as compared to the other techniques used in the study. Retardation in the polymerization process was seen in precooled putty group, which may make this technique clinically inadvisable.

Clinical significance: Thermal protection of pulp must always be considered during direct fabrication of provisional restoration when a PMMA-based resin is used. By using on–off technique, not only the thermal insult to the pulp can be effectively minimized but also the harmful effects of residual monomer (poor marginal fit and pulpal irritation) can be eliminated.

Keywords: Cooling techniques, Intrapulpal temperature, Laboratory research, Polymethyl methacrylate, Provisionalization.

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INTRODUCTION

The scope of fixed prosthodontic treatment can range from the restoration of a single tooth to the rehabilitation of the entire occlusion. It is vital that the prepared tooth is protected by means of an interim or provisional restoration till the time definitive prostheses can be delivered.1 The requirements of provisional restoration are biologic (pulp protection, maintaining tooth position, and marginal integrity), mechanical (resist dislodging forces, maintain interabutment alignment, and positional stability), and esthetics.2

Provisional restorations can be fabricated conventionally by three methods, direct, indirect–direct, and indirect technique.3 Indirect method is a healthier option for pulp, yet it is comparatively time consuming due to additional laboratory work. Although the direct technique seems more elementary and simple, but the problems associated with it are, the presence of free residual monomer, causing soft tissue lesions, contact dermatitis, and the increase in pulp chamber temperature by provisional resins.4–6 The amount of heat transferred to the pulp chamber during the polymerization of resins may exceed the critical threshold and cause thermal damage to the dental pulp and odontoblasts.7 Zach and Cohen demonstrated that a 5.5°C intrapulpal temperature rise lead to necrosis of the pulp in 15% of the teeth, an 11.1°C rise resulted in necrosis of pulp in 60% of teeth and a 16.6°C rise lead to necrosis of 100% of the teeth.8 Therefore, thermal protection of pulp by using cooling techniques or insulation methods is one of the principle biological requirements.

The on/off technique, precooled putty index technique, and application of dentin bonding agent (DBA) as an insulating medium have shown maximum efficiency in reducing the intrapulpal temperature during direct temporization, when assessed separately by different authors under different experimental settings.9–11 No study in present literature has compared the efficiency of these cooling techniques together.
Hence, this study evaluates and compares the changes in pulp chamber temperature during direct fabrication of provisional restorations using polymethyl methacrylate (PMMA) resin, after an external on/off cooling, an insulating DBA application, and a precooled putty index technique.

The null hypothesis is that there would be no significant difference in the rise in the pulp chamber temperature between the three cooling and insulating groups and the control group.

**Materials and Methods**

This original research study was conducted at Department of Prosthodontics in College of Dental Sciences, Davangere, Karnataka. Ethical approval for the study was obtained from the College of Dental Sciences, Institutional review board.

Total samples of 60 extracted maxillary central incisors were collected from different private dental clinics in Davangere and were stored in 10% formalin solution. The teeth had been extracted mostly due to periodontal reasons. Samples were then equally divided among four groups (15 samples each for one control and three experimental groups). For standardization purposes and tooth samples to meet the inclusion criteria, three criteria were adopted. First, intraoral periapical radiograph was taken for every tooth to exclude any caries, calcified pulp chamber, or canal and to ensure sufficient tooth structure and a normal pulp chamber morphology. Second, visual examination of the tooth to exclude attrition, cervical abrasion, bleached tooth, or tooth with any restoration. Third, vernier caliper to measure the crown mesiodistal width (8–10 mm) and cervicoincisal length (10–12 mm).

The central incisors were mounted perpendicular to a rectangular platform (40 mm × 25 mm) made using auto-polymerizing resin (Coltene). Four equidistant notches were cut in the resin block using an acrylic trimming carbide bur, around the tooth sample to facilitate orientation. Using polyvinyl siloxane material (3M ESPE Express XT Putty), two putty indices were made for each sample (Fig. 1). The first index assessed the even crown preparation and the second index was subjected to provisionalization.

Tooth preparation of 2 millimeters (mm) on occlusal surface and 1.5 mm on all the axial walls with 10° convergence was done using the surveyor cum milling machine (BEGO, Paraskop M, model-26340) for standardization purpose (Figs 2 and 3A). Using a micromotor (KAVO S 600) and carborundum disk, all the samples were sectioned approximately 2 mm below the cementoenamel junction. The pulp chamber was cleaned using 3% sodium hypochloride (SD Fine chemicals) and the radicular portion enlarged using Peeso reamers (Zerodegree, DENTSPLY).

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The ends of the 0.6 mm K type thermocouple wire alloy were soldered together with lead wire, using microsoldering iron station (Oswal Electronics) and solder flux. The soldered tip was then passed through the enlarged root apex and stabilized at pulp chamber roof by condensing amalgam (D.P.I and MAARC) in pulp chamber (Fig. 3B). Radiographs were taken to ensure this after the two portions of the sectioned tooth were then approximated together using cyanoacrylate adhesive (Fig. 3C).

The tooth-thermocouple assembly (Fig. 3D) was placed in water bath (Matri, Model-3320) at 37°C and allowed to thermally equilibrate before application of tooth resin material (D.P.I self-cure tooth molding powder). The tooth resin material was manipulated as per the manufacturer’s instructions (1 g of powder in 0.5 mL of monomer liquid and thorough mixing for 20 seconds). The resulting mix was then filled inside the putty index and the temperature indicator device (Selec TC-544 model) was used to record the rise in the pulp chamber every 5 seconds over a 10 minutes period, till the temperature again reaches the baseline temperature.

- **Control group**—Putty index filled with poly resin mixture and positioned on the tooth. The temperature was displayed on the temperature indicator device and noted (Fig. 4A).
- **On/off group**—Same as control except, the provisional restoration was elevated from the abutment, completely exposing the prepared tooth, after initial polymerization, i.e., when resin had reached a rubbery consistency (approximately 5 minutes 10 seconds for this material). Tooth was then flushed with an air-water spray using a three-way syringe for 2 seconds and then replaced onto the tooth. Removal and flushing were repeated every 5 seconds (Fig. 4B).
- **Precooled putty group**—The putty index was precooled in a domestic refrigerator (Godrej Eon, model-GFE36B/2007) at 4°C for 30 minutes before filling the resin mixture in it and temperature change recorded (Fig. 4C).

![Fig. 1: Mounted maxillary central incisor with putty index of unprepared tooth](image1)

![Fig. 2: Tooth preparation using surveyor–cum–milling machine](image2)
To reduce the bias, blinding was performed using a barrier between the temperature indicator and the tooth sample, where a trained laboratory technician recording the temperature readings was unaware of the allocated group sample being used, and the

- **DBA group**—Two layers of dentin adhesive (3M ESPE, Single Bond Universal Adhesive) were coated on the tooth and cured using light curing unit (Ivoclar Vivadent, Bluephase Style), followed by the procedure as in control (Fig. 4D).
application of cooling techniques was performed by the authors. Temperature changes per 5 seconds, of all 15 samples were averaged to determine the mean values of temperature rise for that particular group. A temperature rise of less than 5.5°C was considered favorable and set as the critical temperature as per Zach and Cohen's criteria. Using one-way ANOVA, the mean of the highest intrapulpal temperature was noted from the baseline temperature. The standard deviation and standard error were calculated. Using the standard deviation and mean, Tukey post hoc analysis was further done to compare the data between every group (Tables 1 and 2).

RESULTS

It was found that the mean of the highest temperature recorded, in each group, was highly statistically significant when they were compared to each other, as the p-value of each group was less than 0.001. The highest mean obtained among the groups was of the control—11.04°C, followed by DBA group—9.53°C, precooled putty group—6.67°C, and on–off group—1.94°C (Table 1, Figs 5 and 6).

The maximum amount of time taken to reach the baseline temperature was by precooled putty index group—847.5 seconds followed by DBA group—733.4 seconds, control group—665.9 seconds, and on–off group—653.7 seconds (Table 3).

DISCUSSION

The null hypothesis was rejected as the difference between the control group and experimental groups was highly significant. It was seen that the results were statistically significant overall using one way ANOVA test, as the p-value was <0.001 for every group. Tukey post hoc analysis, further concluded that the mean of the highest temperature recorded, in each group, was highly statistically significant when they were compared to each other, as the p-value of each group was <0.001.

The study was performed on PMMA resin instead of other provisional materials available like polyethyl methacrylate, polyvinyl ethyl methacrylate, bisacrylic composite, or urethane dimethacrylate, as the temperature increase recorded for PMMA was significantly higher compared to others, and thereby the competence of the tested cooling techniques could be determined effectively.

In the control group, a sudden hike in the temperature recorded was 11°C more than the baseline temperature, which in accordance to Zach and Cohen might result in irreversible pulp damage in 60% of cases. The maximum mean temperature recorded in precooled putty group from the baseline value was approx. 7°C, as compared to 11°C in control group. The difference between these two values is nearly 4°C, which is in accordance to the results obtained by Chiodera et al., in which the difference between the control and cooled putty group was 4.1°C. However, the maximum temperature readings could not be correlated, as the resin material used in that study was bis-acryl type. In this case, a sudden hike in temperature was noted for single application of cooling techniques 

Table 1: Comparison of temperature variation between study groups

| Study groups       | N   | Mean | SD  | Min | Max  |
|--------------------|-----|------|-----|-----|------|
| Control            | 15  | 11.04| 0.42| 10.60| 11.60|
| DBA                | 15  | 9.53 | 0.05| 9.50 | 9.60 |
| Precooled putty    | 15  | 6.67 | 0.15| 6.50 | 7.00 |
| On–off             | 15  | 1.94 | 0.33| 1.70 | 3.10 |

One-way ANOVA

|                      | F     | p value |
|----------------------|-------|---------|
| Control              | 3398.53| <0.001* |

*p <0.05, statistically significant, p >0.05; NS, nonsignificant

Table 2: Pairwise comparison of temperature variation using Tukey post hoc test

| (I) Group      | (J) Group     | Mean difference (I–J) | Std. error | p-value  |
|----------------|---------------|-----------------------|------------|----------|
| Control        | DBA           | 1.51                  | 0.10       | <0.001*  |
| Control        | Precooled putty | 4.37                  | 0.10       | <0.001*  |
| DBA            | Precooled putty | 2.86                  | 0.10       | <0.001*  |
| Precooled putty| On–off        | 7.59                  | 0.10       | <0.001*  |
| Precooled putty| On–off        | 4.73                  | 0.10       | <0.001*  |

95% CI

|                      | Lower bound | Upper bound |
|----------------------|-------------|-------------|
| DBA                  | 1.24        | 1.78        |
| Precooled putty      | 4.10        | 4.64        |
| On–off               | 8.83        | 9.37        |
| Precooled putty      | 8.83        | 13.13       |
| On–off               | 7.32        | 7.86        |
| Precooled putty      | 4.46        | 5.00        |

*p <0.05 statistically significant, p >0.05; NS, nonsignificant

Table 3: Mean time taken to reach the baseline temperature (37°C), by every group

| Groups                | Mean time taken to reach the baseline temperature (in seconds) |
|-----------------------|---------------------------------------------------------------|
| Control group         | 665.9                                                         |
| On–off group          | 653.7                                                         |
| Precooled putty group | 847.5                                                         |
| DBA group             | 733.4                                                         |

Fig. 5: Comparative values of highest intrapulpal temperature attained from baseline (37°C) by all experimental groups
The study had some limitations. First, the temperature values measured in this study cannot be directly applied to the temperature changes \textit{in vivo} due to the absence of blood circulation in the pulp chamber. Second, due to the loss of the dentinal fluid in extracted human teeth with time, the measurements noted in this study cannot be exact as inside the pulp chamber \textit{in vivo}, as the fluid may promote heat convection. Third, the neural regulatory systems of the pulp, prostaglandin mediated inflammatory process cannot be simulated in the study. Fourth, different formulations of PMMA resins commercially available may be expected to behave slightly different from our test results.

**CONCLUSION**

Within the limitations of this study, following conclusions can be made.

- On–off technique is the most effective method to reduce the intrapulpal temperature during polymerization, as compared to the other techniques used in the study, making this technique highly significant in decreasing the intrapulpal temperature both statistically and clinically.

- Although the precooled putty method is more effective than DBA method, there exists a possibility of irreversible pulpal damage in more than 15% teeth.

**CLINICAL SIGNIFICANCES**

- Thermal protection of pulp must always be considered during direct fabrication of provisional restoration when a PMMA resin is used.

- The amount of time taken to reach the baseline temperature (37°C) was highest in precooled putty group, indicating retardation in the polymerization process, which may make this clinically inadvisable.

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