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

Rajat R. Khajuria1, Ravi Madan2, Swatantra Agarwal2, Reecha Gupta1, Sunil V. Vadavadgi3, Vikas Sharma2

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, 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.18 stated that approximately 1–2 million dentinal tubules are exposed during an average tooth preparation of a posterior crown, which may lead

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

How to cite this article: Khajuria RR, Madan R, Agarwal S, Gupta R, Vadavadgi SV, Sharma V. Comparison of temperature rise in pulp chamber during polymerization of materials used for direct fabrication of provisional restorations: An in-vitro study. Eur J Dent 2015;9:194-200.

Copyright © 2015 Dental Investigations Society. DOI: 10.4103/1305-7456.156807
to severe sensitivity to the patients or even death of pulp 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](image)

| 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 Krukal–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
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 of exothermic heat released by resins increases with increased number of vinyl groups which is directly related to resin volume. Bis-acrylic composites have
Khajuria, et al.: Temperature changes in pulp chamber during direct fabrication of provisional restorations

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 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

| 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 |             |        |             |

aR²=0.684 (adjusted R²=0.672)
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 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.

**REFERENCES**

1. Richards D. Oral diseases affect some 3.9 billion people. Evid Based Dent 2013;14:35.
2. Robinson HB, Lefkowitz W. Operative dentistry and pulp. J Prosthet Dent 1962;12:965-1001.
3. Skurow HM, Nevins M. The rationale of the preperiodontal provisional biologic trial restoration. Int J Periodontics Restorative Dent 1988;8:8-29.
4. Ivkonic N, Bozovic D, Ristic S, Mirjanic V, Jankovic O. The residual monomer in dental acrylic resin and its adverse effects. Contemp Mater 2013;4:85-91.
5. Wiltshire WA, Ferreira MR, Ligthelm AJ. Allergies to dental materials. Quintessence Int 1996;27:513-20.
6. Zach L, Cohen G. Pulp response to externally applied heat. Oral Surg Oral Med Oral Pathol 1965;19:515-30.
7. Driscoll CF, Woolsey G, Ferguson WM. Comparison of exothermic release during polymerization of four materials used to fabricate interim restorations. J Prosthet Dent 1991;65:504-6.
8. Rawls HP. Dental polymers. In: Anusavice KJ, editor. Phillips Science of Dental Materials. 11th ed. St. Louis: Elsevier; 2003. p. 143-66.
9. Ferracane JL, Greener EH. Fourier transform infrared analysis of degree of polymerization in unfilled resins – methods comparison. J Dent Res 1984;63:1093-3.
10. Stansbury JW, Dickens SH. Determination of double bond conversion in dental resins by near infrared spectroscopy. Dent Mater 2001;17:71-9.
11. Daronch M, Rueggeberg FA, Hall G, De Goes MF. Effect of composite temperature on in vitro intrapulpal temperature rise. Dent Mater 2007;23:1283-8.
12. Oztürk B, Usüméz A, Oztürk AN, Ozer F. In vitro assessment of temperature change in the pulp chamber during cavity preparation. J Prosthodont Dent 2004;91:436-40.
13. Xie C, Wang Z, He H, Han Y. In vitro pulp chamber temperature rise during fabrication of provisional restorations on different types of teeth. Int Chin J Dent 2007;7:69-74.
14. Vallittu PK. Peak temperatures of some prosthetic acrylates on polymerization. J Oral Rehabil 1996;23:776-81.
15. Moulding MB, Teplitky PE. Intrapulpal temperature during direct fabrication of provisional restorations. Int J Prosthodont 1990;3:299-304.
16. Michalakis K, Pissiotis A, Hirayama H, Kang K, Kafantaris N. Comparison of temperature increase in the pulp chamber during the polymerization of materials used for the direct fabrication of provisional restorations. J Prosthodont 2006;96:418-23.
17. Trowbridge HO, Franks M, Korostoff E, Emiling R. Sensory response to thermal stimulation in human teeth. J Endod 1980;6:405-12.
18. Tjan AH, Grant BE, Godfrey MF 3rd. Temperature rise in the pulp chamber during fabrication of provisional crowns. J Prosthodont Dent 1989;62:622-6.
19. Chiodera G, Gastaldi G, Millar BJ. Temperature change in pulp cavity in vitro during the polymerization of provisional resins. Dent Mater 2009;25:321-5.
20. Akova T, Ozkomur A, Dundar C, Aytutuldu N. Intrapulpal heat generation during provisionalization: Effect of desensitizer and matrix type. J Prosthodont 2008;17:108-13.
21. Usüméz A, Oztürk AN, Aykent F. The effect of dentin desensitizers on thermal changes in the pulp chamber during fabrication of provisional restorations. J Oral Rehabil 2004;31:579-84.
22. Kim SH, Watts DC. Exotherm behavior of the polymer-based provisional crown and fixed partial denture materials. Dent Mater 2004;20:383-7.
23. Yondem I, Altintas SH, Usüméz A. Temperature Rise during Resin Composite Polymerization under Different Ceramic Restorations. Eur J Dent 2011;5:305-9.
24. Malcic AI, Pavicic I, Trošić I, Simeon P, Katanec D, Krmek SJ. The effects of bluephase LED light on fibroblasts. Eur J Dent 2012;6:311-7.