

An *in-vitro* study to compare the temperature rise in the pulp chamber by direct method using three different provisional restorative materials

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Abstract

Statement of Problem: The provisional restorative materials in fixed prosthodontics are basically bis-GMA resins which releases exothermic temperature while polymerization which can damage the pulp. Intrapulpal temperature exceeding 42.5°C found to result in irreversible damage to the pulp. The remaining thickness of dentine after tooth preparation control the conduction of heat released by the resins.

Purpose: (1) To quantify the temperature changes in the pulp chamber using different provisional restorative materials. (2) To evaluate the peak temperature time of different materials used. (3) To compare the intrapulpal temperature changes with a variation in the width of the finish line.

Methodology: Two intact mandibular molars were selected and designated as Specimen A and B. Tooth preparation was done to prepare a finish line of 1.2 mm and 1 mm width, respectively. Three provisional restorative materials were considered and they were grouped as Group I-Cool temp, Group II-Protemp-4, Group III-Integrity. A J thermocouple probe was placed into the pulp chamber to determine the rise in temperature. The temperature was recorded during polymerization at 30-s intervals until the peak temperature was reached. The same procedure was repeated for fabricating remaining provisional crowns. A total of 45 provisional crowns were fabricated for each specimen.

Results: Kruskal–Wallis test revealed that there was a significant difference in the temperature changes associated with the provisional restorative materials used. All the three provisional restorative materials were compared for 1.2 mm and 1 mm wide finish line. Integrity produced the highest temperature rise and the maximum temperature recorded was 40.2°C in 1.2 mm wide finish line. However, for a 1 mm wide finish line, Protemp-4 produced the highest temperature rise and the maximum temperature recorded was 40.3°C. It was observed that peak temperatures with Specimen B were more when compared with Specimen A.

Conclusion: Cool temp showed least temperature rise in the pulp chamber. The order of rise in intrapulpal temperature in tested provisional materials using direct technique would be Cool temp, Integrity, and Protemp-4.

Key Words: Direct technique, intrapulpal temperature rise, provisional restorations, residual dentin thickness, width of finish line

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INTRODUCTION

Many of the provisional restoration materials are self-curing in nature, and they tend to produce exothermic heat

during polymerization. When the resin is in direct contact with cut dentin, a considerable amount of heat may be transmitted to the pulp chamber this may result in thermal pulp damages.^[1] A low curing temperature of the resin is desirable to avoid thermal pulp damages while fabricating direct temporary restorations. The temperature transferred to the pulp chamber is dependent on variables related to the clinical manipulation of these materials, that is, fabrication technique, type of matrix used, as well as the remaining thickness of the cut dentin wall.^[2] Stanley reported that when external heat was applied to intact teeth, a 5.6°C rise in the temperature of the pulp caused 15% of the pulps tested to lose vitality, a 11.2°C rise in the temperature caused 60% of the pulps to lose vitality, and a 16.8°C rise in the temperature caused irreversible pulpal necrosis in 100% of the pulps.^[3] Interim restorations should be removed before a 5.6°C rise in temperature to avoid pulpal insults. Selecting an appropriate interim material, minimizing the volume of material, and choosing an appropriate fabrication technique limit the thermal insult to the pulp.^[4] Since literature search doesn't reveal any study which takes into consideration the temperature changes with a variation in the width of the finish line or residual dentin layer thickness, the objective of the present study was to compare peak temperature changes in the pulp chamber using different provisional restorative materials, and to compare the temperature changes with a variation in the width of the finish lines.

The null hypothesis of the present study is that since all the three provisional restorative materials used in the study are having same composition there will not be much difference in the temperature rise in the pulp chamber.

METHODOLOGY

Preparation of specimen

Two extracted mandibular molars with normal morphology were selected for the study. The roots of the teeth were independently embedded in to dental stone block leaving the coronal part, up to 1 mm below the cemento-enamel junction (CEJ) of the tooth open to work. The tooth embedded in dental stone was positioned on the cast holder of the dental cast surveyor and the specimens were designated as Specimen A and Specimen B. A silicone index was prepared to assess the tooth preparation.

Preparation of template for provisional

Polyvinyl siloxane impressions of both the specimens were made and casts were poured in dental stone. 2 mm thermoplastic sheet (Bioplast Vaccum formed Polyvinyl sheet) was adapted to create a template for provisional restoration. Three templates for each tooth were prepared.

Preparation of teeth

In order to standardize the tooth preparation, an air rotor straight headpiece (NSK-JAPAN) was mounted onto the vertical arm of the dental cast surveyor (Sae Yang) [Figure 1]. Flat end taper diamond points with a tip diameter of 1.2 mm (TF-I4 ISO-172/023) and 1 mm (TF-I3, ISO-173/018) were used to prepare axial surfaces and the finish lines. Preparation was done carefully watching the tip of the diamond point to the complete depth. This resulted in 1.2 mm shoulder on Specimen A and 1 mm shoulder on Specimen B, respectively. The specimen were removed from the surveyor and the teeth were further prepared on occlusal surface conventionally to receive a full veneer crown. The prepared teeth were evaluated with the index for uniform reduction. The dimensions of finish line and uniformity were confirmed by observing under a stereomicroscope (Olympus SZX 16) [Figures 2 and 3].

After recovering the teeth from stone blocks, the root portion 4 mm below the CEJ was sectioned horizontally. An opening was made into the pulp chamber through radicular approach to facilitate insertion of the thermocouple. The pulp chamber was cleaned to remove all organic remnants using 5.25% sodium hypochlorite. A J thermocouple probe was inserted into the dry pulp chamber and silver amalgam was condensed to surround and stabilize the thermal probe in positions. Amalgam condensation around the thermal probe facilitated the transfer of heat transmitted through the dentin to the pulp chamber to the thermocouple.

Provisional restorations and testing

Each Tooth was then embedded in square acrylic resin block along with thermocouple [Figures 4 and 5]. The tooth was placed in a water bath (Dalal tissue water bath) containing distilled water of 37°C temperature to equilibrate the tooth temperature with oral temperature [Figure 6]. The tooth was



Figure 1: Tooth positioned on cast holder on surveyor and handpiece attached to the surveying arm

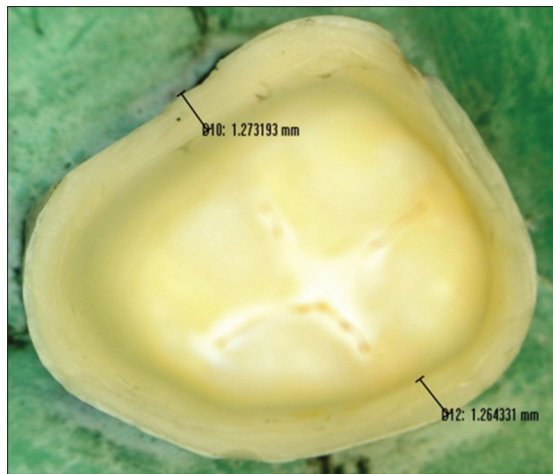


Figure 2: Stereomicroscope picture showing 1.2 mm wide finish line

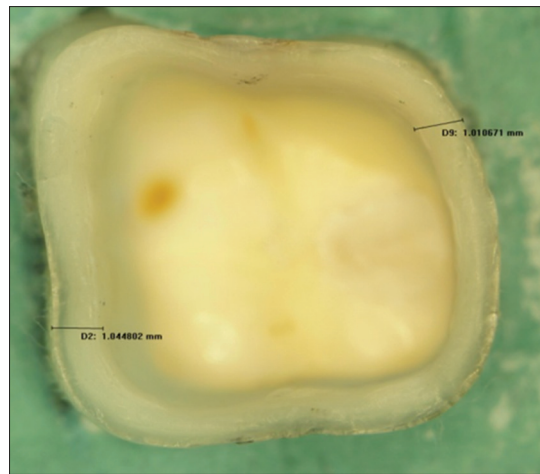


Figure 3: Stereomicroscope picture showing 1 mm wide finish line



Figure 4: Acrylic resin block with 1.2 mm wide finish line



Figure 5: Acrylic resin block with 1 mm wide finish line

allowed to thermally equilibrate. A thin layer of petroleum jelly lubricant was applied to the total assembly to facilitate removal of provisional crowns. The vacuum-formed template filled with mixed resin was positioned on the prepared molar tooth. Excess resin material was removed and the tooth was placed immediately in the water bath of 37°C to simulate oral temperature. The temperature change in the pulp chamber was recorded during polymerization at 30-s intervals. After complete polymerization of the resin material, the template was removed from the tooth and the provisional crown was retrieved. The tooth was cleaned to remove any resin residue, and was placed in the water bath again to equilibrate to 37°C; same procedure was repeated to fabricate the remaining provisional restorations. Both the specimens were stored in distilled water while not being used.

Three materials were evaluated: (1) Cool temp (Coltene whaledent), (2) Protemp IV (3MESPE), (3) Integrity (Dentsply). 15 provisional restorations were prepared for each material. A total of 45 provisional crowns were prepared for Specimen

A and 45 provisional crowns for each Specimen B. A single operator was used for manipulation and fabrication of all the provisional restorations. The recorded temperature changes were tabulated for statistical analysis.

After the provisional resin materials were evaluated, the teeth were sectioned buccolingually using a diamond disk under copious coolant. The residual dentin thickness was measured at various locations using stereomicroscope. An average dentine thickness was determined for both the molars.

RESULTS

The statistical analysis was carried out using SPSS Software by IBM Corporation. The tests applied were Kruskal–Wallis test, Wilcoxon Signed rank test and Mann–Whitney U-test.

Comparison of three provisional restorative materials for 1.2 mm wide finish line, Integrity produced the highest temperature rise and the maximum temperature recorded was



Figure 6: Tooth-thermocouple assembly showing baseline

40.2°C after 1 min and the mean value was 40.25°C. Maximum temperatures recorded for Cool temp and Protemp-4 were 38.9°C and 39.61°C and the mean values obtained for Cool temp and Protemp-4 were 38.9°C and 39.6°C, respectively [Graph 1].

Comparison of three provisional restorative materials for 1 mm wide finish line, Protemp-4 produced the highest polymerization temperature rise and the maximum temperature recorded was 40.3°C after 1.5 min and mean value was 40.3°C. Maximum temperature recorded for Cool temp and Integrity was 38.9°C and 40.0°C and the mean values obtained for Cool 5 temp and Integrity was 38.9°C and 40.0°C, respectively [Graph 2].

The average dentinal thickness for Specimen A was 3 mm at the occlusal surface and 1.8 mm and 1.6 mm at the cervical areas [Figure 7]. Average dentinal thickness for Specimen B was 2 mm at the occlusal area and 1 mm and 2 mm at the cervical areas, respectively [Figure 8].

DISCUSSION

The pulp consists of numerous connective tissue cells, fibers, and ground substance. Among these, cells are highly specialized odontoblasts, which are related to primary and secondary dentin formation.^[5] Injury to the pulp during prosthodontic procedure may be caused by thermal effects like heat produced during tooth preparation and fabrication of provisional restorations.^[4] Histologic study to assess the pulp response to external applied heat has demonstrated that a temperature increase of 2.3°C was confined only to the odontoblasts that were next to the area of thermal injury. The intrapulpal temperature rise by 5.6°C showed remarkable pulpal response, including destruction of most of the odontoblasts, displacement of nuclei into the dentinal tubules, reduction of thickness of uncalcified predentin, denaturation of matrix that were next to the area of thermal injury.

Interim restorations are an essential part of fixed prosthodontic treatment. Need of such prostheses is multifactorial. The provisionals are used to assist in determination of the therapeutic effectiveness of a specific treatment plan and also the form and function of the planned definitive prosthesis. A good provisional restoration will protect pulpal tissue and sedate prepared abutments, protect teeth from dental caries, provide comfort and function, evaluate parallelism of abutments, prevent migration of abutments, improve esthetics, evaluate and reinforce the patient's oral hygiene, provide anchorage for orthodontic brackets during tooth movement, aid in developing and evaluating an occlusal scheme before definitive treatment, allow evaluation of vertical dimension, phonetics, and masticatory function.^[6]

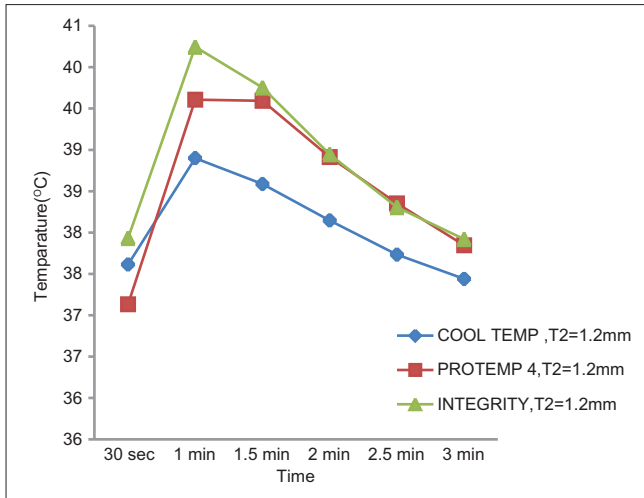
Mechanical, physical, and handling properties, as well as biocompatibility, will influence the material selection in fabricating provisional restorations. A material should be easy to handle, provide adequate working time, and be nontoxic. Treatment complications such as chemical injury from the presence of monomer residue, thermal injury from an exothermic polymerization reaction, and mechanical injury resulting from polymerization shrinkage must be considered.^[5]

Studies have shown that healthy pulps failed to recover from an intrapulpal temperature rise of 5.55°C in 15% of the situations. When the intrapulpal temperature increased by 11.1°C and 16.65°C, 60% and 100% of the teeth, respectively, lost vitality.^[3]

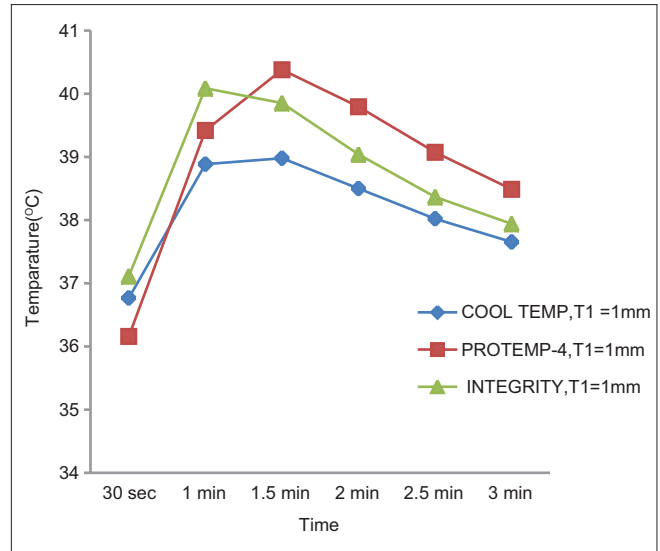
Dentin behaves as a thermal barrier against harmful stimuli. The greater the remaining dentin thickness, the greater is the protection to the pulp.^[1,7,8]

A 2 mm of residual dentin thickness showed an increase in temperature from 1°C to 3°C and if residual dentin thickness was 1 mm, an increase in temperature from 2°C to 4°C was noted. The results of our study are in accordance of study wherein the residual dentin thickness of 2 mm demonstrated an increase in temperature from 0°C to 3°C and residual dentin thickness of 1 mm resulted in an increase in temperature ranging from 0°C to 4°C. This is indicative of a minimum 1 mm of residual dentin thickness is necessary to protect the pulp from temperature rise caused by the exothermic reaction of provisional materials.^[9]

The results of our study showed that peak temperature for Cool temp, Protemp-4, and Integrity for Specimen B (having 1 mm wide finish line) was greater when compared to Specimen A (having 1.2 mm wide finish line). This was in contrast to earlier studies which showed an increase in temperature with a reduced thickness of dentin.^[7,8] However, surprised by the



Graph 1: Comparison between Cool temp, Protemp, and Integrity temp in Specimen A = 1.2 mm



Graph 2: Comparison between Cool temp, Protemp, and Integrity temp in Specimen B = 1 mm

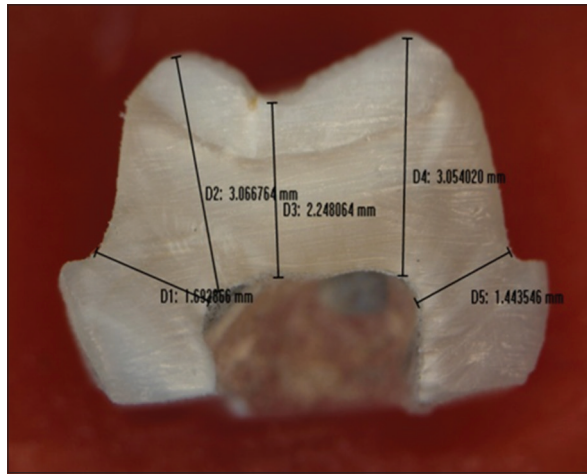


Figure 7: Sectioned Specimen A with 1.2 mm wide finish line showing remaining dentin thickness

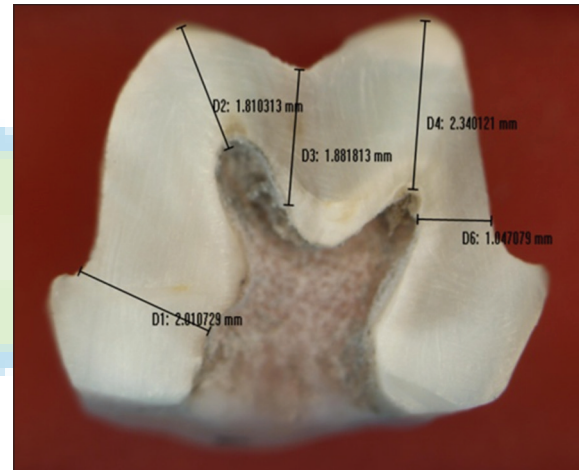


Figure 8: Sectioned Specimen B with 1 mm wide finish line showing remaining dentin thickness

results, the teeth were further sectioned to visualize the actual residual dentin thickness. Remaining dentin thickness in Specimen A at various locations were 3 mm and 2 mm and at the cervical area it was 1.8 mm and 1.6 mm, respectively. Enamel was present in Specimen A, but there was no secondary or sclerotic dentin in it.

Remaining dentin thickness for Specimen B was 1 mm and 2 mm at various locations and at the cervical area also it was 1 mm and 2 mm, respectively. Enamel was absent in Specimen B and there was only 1 mm dentin thickness in one region. Therefore, exothermic heat was transferred in larger amounts. In Specimen B, sclerotic dentin was found and recent studies have shown that the dentin with higher degree of mineralization conducts better resulting in a higher temperature increase in the pulp chamber as there is a strong correlation between the open porosity of human dentin and its thermal conductivity, as open porosity decreases the thermal conductivity increases.

Highly mineralized dentin, such as the sclerotic dentin as seen in Specimen B of our study, has low open porosity and tortuous dentinal tubules with smaller diameters. Therefore, it was seen that Specimen B allowed a higher thermal transfer to the pulp chamber.^[9] All the materials used were in the safety limit although there was a significant difference of 0.0001 between all the three provisional restorative materials hence the null hypothesis was rejected.

Whenever the fabrication of provisional restorations by direct technique is preferred, precautionary measures must be used to minimize intrapulpal temperature rise due to exothermic reactions of the resins. Cooling the material during polymerization by its removal at initial polymerization, using an air-water spray, periodic removal, flushing with water, use of a “heat sink” matrix material such as alginate and allowing

complete polymerization off the tooth will limit temperature increases to $<4^{\circ}\text{C}$, thus minimizing the exothermic risk. The clinician should limit the thermal insult to the pulp by selecting an appropriate interim material, minimizing the volume of material, and choosing an appropriate fabrication technique.^[7]

The order of rise in peak temperatures in the pulp chamber using provisional materials by direct technique would be Cool temp, Integrity, Protemp-4. Cool temp and Integrity can be used when there is less residual dentin thickness and Protemp-4 is preferred when the residual dentin thickness is more.

The results of our study have shown variation in temperature rise related to width of the finish line due to variation in thickness of residual dentin and difference in thermal conductivity of dentin.

CONCLUSION

Clinical significance

Clinicians should be aware of increased temperature levels associated with the direct fabrication of provisional restorations. Within the scope of this study, bis-acryl composite resin proved to be predictable material for the efficient fabrication of provisional restorations. A comparison of temperature changes in the pulp chamber using three different provisional restorative materials showed that all the materials produced an increase in temperature during polymerization, but all the materials used were within the safety limit.

- Cool temp showed the least temperature rise in the pulp chamber. The order of rise in peak temperatures in the pulp chamber using provisional materials using a direct technique would be Cool temp, Integrity, and Protemp-4, respectively
- Peak temperature was highest for Protemp-4 followed by Integrity and Cool temp, respectively

- A thinner residual dentin compared to Specimen A resulted in higher intrapulpal temperature rise.

Limitations of the study

(1) X-ray of the samples were not taken before the procedure hence the residual dentin thickness was not evaluated. (2) Blood circulation and fluids in the pulp chamber could not be simulated. Further studies are recommended to compare the temperature changes in the pulp chamber with variation in the width of the finish line and regarding thermal conductivity of dentin.

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