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Original Research Article

Effect of Cooling Techniques on Pulpal Temperature on Direct Fabrication of Provisional Restorations: An In Vitro Study

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ABSTRACT

Provisional restorations are required before definitive restorations are inserted to protect prepared teeth, reduce dentinal sensitivity, prevent tooth migration with occlusal changes, and to restore function. The purpose of this in-vitro study was to compare the effectiveness of different cooling techniques in minimizing heat transfer to the pulp during direct fabrication of provisional restorations.
Objective: To compare the relative efficacy of different cooling techniques which can be used during direct fabrication of provisional restorations. To compare the temperature rise in the pulp with two different provisional restorative materials.
Method: This laboratory based study was conducted to evaluate: a) The relative efficacy of different cooling technique which can be used during direct fabrication of provisional restorations. b) "Cooled" polyvinyl siloxane putty index and irreversible hydrocolloid (alginate) index can act as a heat sink for heat of polymerization of provisional resin.c) The intrapulpal temperature variations using two different provisional restorative materials. Three types of matrices were used in the study: a. Vacuum formed template b. PVS putty index c. Irreversible hydrocolloid impression index. A total of 160 provisional restorations were fabricated using 3 matrices and 2 provisional restorative materials. Intrapulpal temperature variations were recorded, tabulated and statistically analysed.
Results: Analysis of variance (ANOVA) technique was used for multiple group comparison followed by Scheffe's Test for pairwise comparison. Intrapulpal temperature variations were recorded, tabulated and statistically analysed.
Conclusion: The temperature rise caused by each matrix decreased in the following order. *Vacuum form template >PVS putty index > irreversible hydrocolloid impression index.*

Keywords: cooling techniques, provisional restorations, Direct Restoration, Indirect Restoration, Vacuum formed template, thermocouple

INTRODUCTION

Provisional restorations are required before definitive restorations are inserted to protect prepared teeth, reduce dentinal sensitivity, prevent tooth migration with occlusal changes, and to restore function. [1-4] Provisional restoration can be fabricated by either "DIRECT" method (i.e. directly on the prepared teeth in the patient mouth) or "INDIRECT" method (i.e. on the stone model/cast. Both methods have their own advantages and disadvantages. [28] Direct method of provisionalization is fast and economical. There is reduction in an extra clinical appointment both for the dentist and the patient. Introduction of composite resins have reduced the free monomer reaching into dentinal tubules. This has made direct fabrication more popular in the present days. Temperature changes from the exothermic reaction of the polymer-based provisional materials have been studied previously. [6- 15] If the temperature increase exceeds, the physiologic heat dissipation mechanisms of the dental-periodontal system, damage could occur, especially to the pulp. [16-18] A temperature rise of 5.50C can lead to a 15% loss of vitality in the pulp, a 110C temperature rise causes about 60% and a 16.60C temperature causes 100% necrosis of the pulp. [19] Various methods involved to reduce damage to the pulp during direct fabrication of provisional restoration include using air / water spray, [12,13] removal of the provisional crown upon initial polymerization, [20] repeated removal and placement of provisional restoration upon initial polymerization while using air / water spray etc. [14] Polyvinyl siloxane impression material act as a heat sink for heat of polymerization. [6,13] Irreversible hydrocolloid (alginate) has shown to produce least temperature rise in pulp when used as a matrix during direct fabrication of provisionals. [11,12] The purpose of this in vitro study was to compare the effectiveness of different cooling techniques in minimizing heat transfer to the pulp during direct fabrication of provisional restoration.

OBJECTIVES:

a. To compare the relative efficacy of different cooling techniques which can be used during direct fabrication of provisional restorations.

b. To evaluate, if cooling of the polyvinyl siloxane putty index and irreversible hydrocolloid (alginate) impression index can prevent temperature rise in the pulp and act as a heat sink for heat of polymerization of provisional resin.

c. To compare the temperature rise in the pulp with two different provisional restorative materials

METHODOLOGY

Fabrication of Study Model:

A model representing a mandibular arch with a missing right first molar was constructed. Extracted natural teeth (first and second premolars and second molar) of average size and form were selected for use in this model. The root was sectioned 3mm below the CEJ of 2nd molar. The pulp chamber was cleaned of organic debris. A thermocouple probe (Cr/Al Type, 1mm diameter, (illustration-3) was positioned inside the pulp chamber and amalgam (DPI, Fine grain, Mumbai, India) was condensed around the probe, filling the pulp chamber. Silver amalgam act as a heat-conduction medium from dentin to the thermocouple probe. The three teeth were placed in their respective position in typhodont rubber dentulous mold. The mold was then completely filled with modelling wax. After solidifying, wax model was retrieved from the mold (photoraph-4). After aligning the natural teeth in the wax model, pontic space was carved in 1st molar region, and the model was refined (photograph-5). This model was invested in stone and acrylized using heat-cure clear acrylic resin (Trevalon, Dentsply, England) using long curing cycle. The acrylic resin model was recovered, trimmed and polished (photograph-6).

Fabrication of Matrices:

An irreversible hydrocolloid impression was made of the wax model and poured in dental stone. A pontic was waxed in place, and this model with waxed pontic was further used in fabrication 3 matrices (photograph-11) i.e.

a. Polyvinyl siloxane putty matrix.
b. Irreversible hydrocolloid matrix
c. Vacuum formed template

(a). Polyvinyl siloxane putty matrix: Equal proportion of base and catalyst material of polyvinyl siloxane putty impression material (Express STD, 3M-ESPE, Germany) were mixed and adapted over the stone cast with waxed pontic. This putty index was used in provisionalization.

(b). Irreversible hydrocolloid (alginate) matrix: Irreversible hydrocolloid (imprint, DPI, Mumbai, India) was mixed according to manufacturers recommendations, loaded in a stock metallic sectional tray and adapted over wet stone cast. Impression was then retrieved and covered with moist gauge pieces to prevent drying of the matrix.

(c). Vacuum formed template matrix: Polypropylene sheets (0.020-inch thickness, buffalo dental, syosset, New York) were used for fabricating the vacuum formed template using a thermal vacuum machine (Sta-Vac, Buffalo Dental, New York).

3. Tooth Preparation and Fabrication of Provisionals: The second premolar and second molar were prepared for complete-coverage porcelain fused to metal retainers (illustration-2 & photograph-9). Using digital radiographic technique (Dexes software) the remaining dentin thickness on prepared 2nd molar was determined (photograph-8). The thermocouple lead was attached to a microprocessor thermometer (Accuracy of the microprocessor thermometer is +/-0.10C) which recorded intrapulpal temperature variation during temporization (photograph-10 & illustration-1). The model was brought to a constant initial room temperature of 25-270C by placing it in a room temperature water bath. Once the intrapulpal temperature was stabilized the model was removed and dried, and a petroleum lubricant was applied to the teeth and surrounding acrylic resin. A small portion of the aluminum foil was adapted over the pontic space and around the gingival areas of the abutment teeth to prevent the provisional resin from adhering to the model.

2 types of provisional resins were used (photograph-6).

a. Polymethyl methacrylate resin, PMMA (DPI, self-cure tooth moulding resin, Mumbai, India.)

b. Bis-acrylic composite resin (protemp II, 3M ESPE, Germany).

The study was divided into 3 groups i.e.

a. Vacuum formed template group.

b. Polyvinyl siloxane putty index group.

c. Irreversible hydrocolloid (alginate) Impression index group.

The 3 groups were further divided into the following sub groups.

GROUP I: Vacuum formed template group (photograph-12). It was further divided into 4 sub-groups.

I (A): “CONTROL”: The provisional restorations were left on the tooth to polymerise without being removed and without the use of coolant.

I (B): “REMOVAL”: The provisional restorations were removed upon initial polymerization and at the beginning of heat rise, detected with finger.

I (C) “IN SITU”: The provisional restorations were left on the abutment teeth throughout the polymerization and an air/water spray (19ml/min) from airrotor handpiece was used to cool the polymerizing resin.

I (D) “ON/OFF”: The provisional restorations were removed from the abutment teeth after initial polymerization along with the matrix, flushing the tooth with an air / water spray (19ml/min) for 2 seconds, and then replacing the restoration. After 5 seconds on the abutment teeth, the provisional restoration was again removed and flushed. This was continued until complete polymerization

GROUP II: Polyvinyl siloxane (PVS) putty index (photograph-13). It was divided into 2 sub- groups.

II(A): “CONTROL”: The provisional restorations were left on the tooth to polymerise without cooling the putty index.

II(B):“COOLED INDEX”: Putty Index was “cooled” in refrigerator (Ambient Temperature 10-120C) for 2 minutes before fabricating the provisionals.

GROUP III: Irreversible hydrocolloid (Alginate) index (photograph-14). It was divided into 2 subgroups.

III (A) “CONTROL”: The provisionals were left on tooth to polymerise without cooling the index.

III (B):“COOLED INDEX”: The alginate index was “cooled” in refrigerator (Ambient temperature, 10-120C) for 2 minutes before fabricating the provisionals.

The resins were placed into the matrix, which was then placed on the prepared abutment teeth. The temperature was recorded at 30-seconds intervals using the microprocessor thermometer. Temperature monitoring was carried out till complete setting of resin according to the time recommended by the manufacturer with evidence of peak temperature during polymerization. The matrix and polymerized resin were removed, and the model with teeth were returned to room temperature before another trial was begun. 10 restorations were fabricated for each technique, for a total of 160 restorations using 2 different provisional resins. Since the materials and models were at room temperature initially, any increase in temperature in the pulp chamber was attributed to the heat of resin polymerization transmitted to the pulp chamber containing silver amalgam and the thermocouple. Intrapulpal temperature variations were recorded, tabulated and statistically analysed.

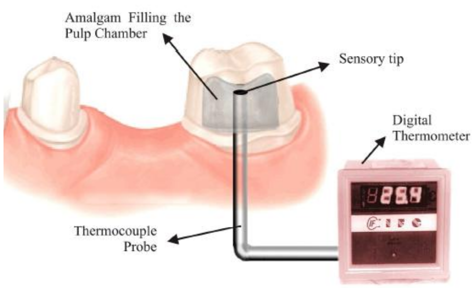

Figure 1: Diagram showing experimental Setup used in the study.

Figure 2: Materials used in the study

Figure 3: Temporary crown and bridge materials used in the study

Figure 4: Wax model with natural teeth 47,45 & 44 in place

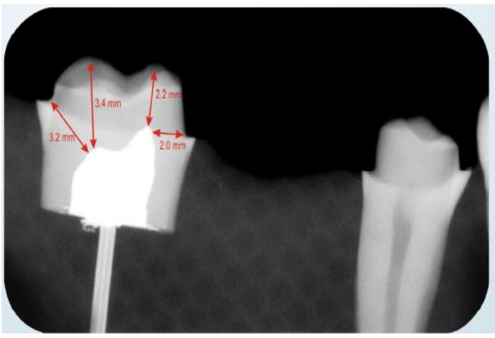

Figure 5: Digital radiographic image of prepared 47 & 45 showing remaining dentin thickness on 47

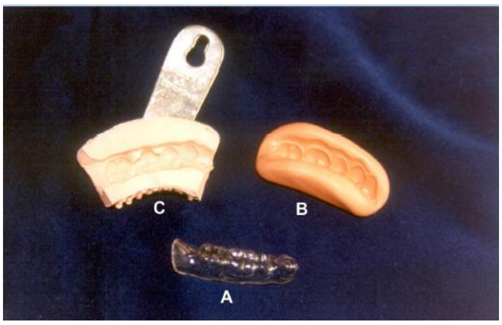

Figure 6: Matrices used in the study Alginate, vacuum formed, PVS putty index

RESULTS

All values were significant at 99% confidence limits.

TABLE 4: Presents comparison of intrapulpal temperature variations between 2 provisional restorative materials. Mann-Whitney test was used for comparison;

p<0.01 was significant and p>0.05 was considered 'not' significant. The following results were obtained.

a. In group (I), "control" and "on/off" cooling technique did "not" show significant difference (p<0.05). But, "removal" and "in-situ" cooling technique showed significant difference (p<0.01)

b. In group (II), both "Control" & "Cooled" index showed significant difference (P<0.01).

c. In group (III), both "Control" & "Cooled" index showed significant difference (P<0.01).

All the description data are presented as mean and standard deviation.

Analysis of variance (ANOVA) technique was used for multiple group comparison followed by Scheffe's Test for pairwise comparison.

TABLE –1 INTRAPULPAL TEMPERATURE VARIATIONS FOR THE 3 GROUPS

Group	Technique	N	DPI – Tooth moulding Resin (0C	Protemp – II (0C)
Group I (Vacuum form template)			Mean SD SE	Mean SD SE
	a) Control	10	8.32 1.09 .35	7.67 .74 .23
	b) Removal	10	2.04 0.34 .11	7.56 .74 .23
	c) In situ	10	3.02 0.51 .16	2.06 .59 .19
	d) On/off	10	2.85 0.81 .26	2.78 .55 .17
Group II (PVS Putty Index)	a) Control b)"Cooled" Index	10 10	4.93 .53 .17 2.43 .49 .15	3.89 .86 .27 1.21 .66 .21
Group III (Alginate Index)	a) Control b)"Cooled" Index	10 10	2.32 .60 .19 0.43 .51 .16	1.11 .86 .27 -0.88 .36 .11

Negative value (-) indicates drop in intrapulpal temperature

TABLE – 2 COMPARISON BETWEEN AND WITHIN GROUPSANOVA TABLE: (DPI-RESIN)

Source	*df*	Sum of squares	Mean square	F Test
Between groups	7	396.8	56.69	134.88
Within groups	72	30.3	.42	P<0.001
Total	79	427.1		

TABLE – 3 COMPARISON BETWEEN AND WITHIN GROUPS ANOVA TABLE: (PROTEMP-II)

Source	*df*	Sum of squares	Mean square	F Test
Between groups	7	659.1	94.16	198.53
Within groups	72	34.1	0.47	P<0.001
Total	79	693.3		

TABLE- 4 COMPARISON OF INTRAPULPAL TEMPERATURE VARIATIONS BETWEEN TWO PROVISIONAL MATERIALS

Group Technique	DPI – Tooth moulding Resin (0C)		Protemp – II (0C)		*p* value*
	Mean	SD	Mean	SD	
Group I (Vacuum Form template) *a)Control*	8.32	1.09	7.67	.74	0.23 NS
b) Removal	2.04	0.34	7.56	.74	<0.01 S
c) In situ	3.02	0.51	2.06	.59	<0.01 S
c) On/off	2.85	0.81	2.78	.55	0.97 NS
Group II (PVS Putty Index) *a) Control*	4.93	0.53	3.89	.86	<0.01 S
b) "Cooled" Index	2.43	0.49	1.21	.66	<0.01 S
Group III (Alginate Index) a) Control	2.32	0.60	1.11	.86	<0.01 S
b) "Cooled" Index	0.43	0.51	-0.88	.36	<0.01 S

*Mann-Whitney's test
p<0.01 Significant (S)
p>0.05 Not Significant (NS)

DISCUSSION

Temporary restorations are fabricated to protect prepared teeth and adjacent gingiva until insertion of the final restoration. They also restore normal tooth function, prevent occlusal changes and tooth migration [3,4] Provisional restorations should be the same as definitive restorations in all aspects, except for the material from which they are fabricated. [2] There are two principal methods in fabrication of provisional restorations i.e. direct and indirect [16,4] Direct method of provisionalization is fast and economical. There is reduction in an extra clinical appointment both for the dentist and the patient. [5] Various materials are available for provisional restorations. These are polymer-based provisional restorative materials e.g. polymethylmethacrylate (PMMA), ethyl methacrylate (EMA), vinyl methacrylate (VMA), bis-acrylic composite, visible-light polymerized composite & butyl methacrylate. [2] The chemical reaction of the polymer-based provisional material is an addition polymerization. The larger heat emission during polymerization, in industry, can cause serious problems. In cases where reaction are rapid, it can lead to thermal explosions. [21] In dentistry, it may cause thermal damage to the vital pulp. [22,17] Pulpal injury can result from exothermic reaction of provisional resin. **Zach and Cohen (1965)** showed that an intrapulpal temperature rise of 5.50C (100F) in *rhesus mecaca* monkey caused 15% of the pulp to loose vitality. [19] Thermal damage include various histopathological changes of the pulp, such as ectopic odontoblasts and their destruction, cellular degeneration, burn reactions at the periphery of the pulp including formation of blisters, coagulation of protoplasm, [17] expansion of liquid in the dentinal tubules and vascular injuries with generalized or localized tissue necrosis, resulting in acute inflammation of pulp, irreversible pulptitis, or pulp necrosis in severe cases. [8,23,22] The heat transferred to the tooth is also influenced by the choice of matrix used to hold the provisional material. [18,11-13] **Moulding and Loney (1991)** [12] evaluated the efficacy of 3 cooling technique i.e. *removal*, *in situ* and *on/off* using vacuum form template and PMMA provisional resin. In this in-vitro study they found that all three cooling techniques were equally effective in preventing the thermal damage to pulp. The authors concluded that "*cooling*" techniques should be used as adjuncts during direct fabrication of provisional. [12] Hence, this study was undertaken to compare the effectiveness of different cooling techniques in minimizing the heat transfer to the pulp during direct fabrication of provisional restorations. The following was the order in heat dissipation for the different matrices used: *Irreversible hydrocolloid matrix > PVS putty matrix > vacuum form template.* [24] For all combinations of provisional resins and marices used, the "*cooled*" alginate index produced the least intrapulpal temperature rise and vacuum form template produced the maximum temperature rise. For the two provisional materials used there was statistically significant difference between the two materials ($p<0.01$) in the groups and the different matrices used for provisionalization. Caution to be taken while interpreting the data from this in-vitro study. In clinical condition, the elevation in temperature is also reduced by presence of the periodontal ligament [22] and other organic structures, such as protoplasmic extension of cells in dentinal tubules. [6] Pulpal and osseous circulation are also effective in heat dissipation. [22,25,24] The thickness of the residual dentin after tooth preparation is a critical factor in reducing the thermal transfer to the pulp. The thermal conductivity of the dentin is only 0.00150C/cm. [26,27] Damage to vital cells can occur even though the thermocouple records no significant rise in temperature. [24] It is not prudent to use a direct technique for making provisional restorations when the remaining dentin is at a minimum or when the tooth has been severely damaged by caries that may have caused some degree of inflammation of the pulp. The same teeth were used throughout this thermographic study to standardize the thickness of the residual dentin and the thermal conductivity because these variables affect the rate of heat flow through the dentin. This relationship may be represented by a modified equation from thermodynamics. [28] H= KA (t2-t1) /D Where 'H' is the quantity of heat flowing through the dentin per unit time, 'K'is the thermal conductivity of dentin, 'A' is the surface area of the tooth exposed to the resin, 'D' is the thickness of the residual dentin, and 't2-t1' is the temperature difference. This equation indicates that the flow of heat through the dentin is directly proportional to the thermal conductivity and inversely proportional to the thickness of the residual dentin. [8] For this study, non-carious teeth with no restoration were selected to decrease variability and to determine if temporary fabrication under ideal circumstances would result in a significant temperature increase. Polymethyl methacrylate (PMMA) has been reported to produce a greater pulpal temperature rise than other available resin. [6,8,12] Direct technique exposes the freshly prepared tooth surface to free monomer during polymerization. To reduce the exposure of free monomer to freshly prepared tooth surface, use of dental varnish or petroleum jelly is recommended prior to temporary fabrication. [4]

SUMMARY AND CONCLUSION

The findings from the study can be summarized as follows:

- The highest intrapulpal temperature rise was recorded using vacuum form template & self cure DPI-Tooth moulding resin i.e. 8.320C +/- 1.09.
- The lowest intrapulpal temperature was recorded using "*cooled*" alginate index & protemp-II i.e. 0.880C +/- 0.36. i.e. drop in intrapulpal temperature from baseline temperature.
- Regardless of the resin used for temporization, the temperature rise caused by each matrix decreased in the following order. *Vacuum form template >PVS putty index > irreversible hydrocolloid impression index.*

The above analysis revealed that "*cooled"* irreversible hydrocolloid index in combination with either of the two provisional restorative materials is the best for preventing intrapulpal temperature rise. From the observation of the study, the following conclusions were drawn:

a) Intrapulpal temperature rise during the direct fabrication of provisional restorations can be limited by employing different cooling techniques. "*Cooled*" irreversible hydrocolloid impression index is the best method for limiting the intrapulpal temperature rise using direct technique of provisionalization.

b) "*Cooling*" of PVS putty and alginate impression index for 2 minutes in refrigerator (Ambient temperature 10-120C) is an effective "*cooling*" method for preventing temperature rise in pulp and can act as a heat sink for polymerization of provisional resins.

c) There was significant difference between the two provisional resins (DPI-self cure tooth moulding powder & protemp-II) for three different matrices used for provisionalization.

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