

Comparative Evaluation of Various Cooling Techniques on Intrapulpal Temperature Rise during Direct Provisionalization - An Ex-vivo Study

Ronauk Singh¹, Parag Dua², Poonam Prakash³, Vijaya Kumar R⁴, S K Bhandari⁵

ABSTRACT

Introduction: Use of autopolymerising resin for direct provisionalization is one of the commonest methods employed by clinicians. However, these materials exhibit an exothermic reaction and are prone to cause pulpal damage. Thus, a combination of cooling technique and matrix material to reduce the quantum of heat transferred to a healthy vital pulpal tissue may be employed for minimal tissue damage. An ex-vivo study was thus envisaged to compare the efficacy of various matrix materials and cooling techniques on time related temperature changes in the pulp chamber during the fabrication of provisional FPD restorations using direct technique.

Material and Methods: A total of 100 provisional restorations were fabricated and were grouped on the basis of three different matrices: Vacuum template, Putty index and Alginate index and further subgrouped on the basis of various cooling techniques employed. Thermal changes in the pulp chamber was evaluated using Cr/ Al thermocouple placed in the pulp chamber of a prepared tooth and connected to a digital thermometer. Intrapulpal temperature variations were recorded, tabulated and statistically analysed.

Results: The inter-group and intra-group statistical comparisons of continuous variables were done using analysis of variance with Bonferroni's correction for multiple group comparisons considering the independent study groups. The underlying normality assumption was tested before subjecting each variable to t test and ANOVA. In the entire study, the p-values less than 0.05 were considered to be statistically significant. All the hypotheses were formulated using two tailed alternatives against each null hypothesis (hypothesis of no difference). The entire data was statistically analysed using Statistical Package for Social Sciences (SPSS ver 21.0, IBM Corporation, USA) for MS Windows.

Conclusion: The order of heat dissipation for the different matrices used is as follows: Irreversible hydrocolloid matrix > PVS putty matrix > vacuum form template. It was concluded that intrapulpal temperature rise during the direct fabrication of provisional restorations can be limited by employing different cooling techniques. "Cooling" of PVS putty and alginate impression index for 2 minutes in refrigerator (Ambient temperature 10-12°C) was found to be most effective "cooling" method for preventing temperature rise in pulp.

Keywords: Cooling Techniques, Intrapulpal Temperature

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.⁵ Direct method of provisionalization is fast and economical. There is reduction in an extra clinical appointment both for the dentist and the patient.⁴ Temperature changes from the exothermic reaction of the polymer-based provisional materials have been studied previously.⁶⁻¹⁰ If the temperature increase exceeds the physiologic heat dissipation mechanisms of the dental-periodontal system, damage could occur, especially to the pulp.¹¹⁻¹⁹ A temperature rise of 5.5°C can lead to a 15% loss of vitality in the pulp, a 11°C temperature rise causes about 60% and a 16.6°C temperature rise causes 100% necrosis of the pulp.¹⁶

Various methods proposed to reduce damage to the pulp during direct fabrication of provisional restoration include using air / water spray, removal of the provisional crown upon initial polymerization, repeated removal and placement of provisional restoration upon initial polymerization while using air / water spray etc.¹⁷ An ex-vivo study was thus conducted to compare the efficacy of various matrix material and cooling techniques on time related temperature changes in the pulp chamber during the fabrication of fixed dental prostheses provisional restorations using direct technique.

MATERIAL AND METHODS

The present ex-vivo study was conducted in the Department of Dentistry, AFMC, Pune. The study was divided into three main groups on the basis of matrix materials and further divided into subgroups on the basis of cooling techniques. Making a total of 100 samples (Table 1).

"Control": The provisional restorations were left on the tooth to polymerise without being removed and without the use of coolant.

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INTRODUCTION

Provisional restorations are required to protect prepared teeth, reduce dentinal sensitivity, prevent tooth migration with occlusal changes, and to restore function.¹⁻⁵ Provisional

“Removal”: The provisional restorations were removed upon initial polymerization and at the beginning of heat rise, detected with finger through vacuum formed sheet. This technique is used only for vacuum formed templates and not for putty and alginate matrix as heat rise detection by finger is not possible in later two.

“In situ”: The provisional restorations were left on the abutment teeth throughout the polymerization and an air/water spray (19ml/min) from air-rotor handpiece was used to cool the polymerizing resin. This method can only be employed for Vacuum form templates as for both Alginate and Putty the thickness of matrix material and impression tray makes external cooling non-effective.

“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. Provisional restoration was removed and flushed every 5 second. This was continued until complete polymerization

“Cooled index”: Alginate and Putty Index were “cooled” in refrigerator (Ambient Temperature 10-12°C) for 2 minutes before fabricating the provisionals

Study model was fabricated by replicating mandibular typodont model with autopolymerising acrylic resin using tooth coloured material for dentate region and pink colored for the rest. Space was provided in 36 region of model to facilitate the access of lead wires attached to thermocouples present in pulp chamber of prepared samples. Tooth sample preparation was done on extracted natural tooth no. 36 of an average size and form.¹⁹ The roots of the extracted prepared tooth were sectioned 3mm below cemento-enamel junction using a diamond disc. After proper cleaning of the pulp chamber, the thermocouple probes (Cr/Al type, 1mm diameter) were positioned inside the pulp chamber and silver amalgam condensed around the probe filling the pulp chamber. After that, the orifice and probes were secured using glass ionomer cement (Figure- 1). Radiovisography was

used to ascertain the proper positioning of the thermocouple inside the abutment teeth and to determine the remaining dentine thickness (RDT) of the prepared tooth (Figure-2). The tooth was then placed in its position in acrylic model (space earlier prepared). The channel for thermocouple wire (earlier prepared) was then filled with pink coloured autopolymerising acrylic resin. The thermocouple lead wire was attached to the digital thermometer which was duly calibrated (Figure-3).

Wax pattern was then fabricated over prepared tooth to make space for provisional restorative material. The working model was duplicated using a polyvinyl siloxane-based impression material and poured using diestone. The diestone model was used to make Vacuum form template, Putty Index and Alginate Index.

The study model was brought to a constant initial room temperature of 24-26°C by placing it in an air conditioned room with controlled ambient temperature. Once the intrapulpal temperature was stabilized, a small portion of the aluminum foil was adapted around the gingival areas of the abutment teeth to prevent the provisional resin from adhering to the acrylic model.

Provisional Material used in this study was Polymethyl methacrylate resin, PMMA (DPI, self-cure tooth moulding resin, Mumbai, India.). Based on the results of previous studies, which showed maximum temperature rise with PMMA^{16,25}, it was selected as the material of choice for the present study as the quantum of thermal change was expected to be significant enough to be noted.

RESULTS

A total of 100 provisional restorations were fabricated using 3 matrices in respective subgroups. The data on continuous variables presented as Mean and Standard deviation (SD) across three study groups. The inter-group and intra-group statistical comparisons of continuous variables was done using analysis of variance with Bonferroni's correction for multiple group comparisons considering the independent study groups. The underlying normality assumption was

Various Matrix Material/ Groups	Subgroups			
	IA “Control”	IB “Removal”	IC “On/Off”	ID “In Situ”
Group I (Vacuum form template):	IA “Control”	IB “Removal”	IC “On/Off”	ID “In Situ”
Group II (PVS putty index)	IIA “Control”	IIB “Cooled”	IIC “On/Off”	NA
Group III (Alginate Impression Index)	IIIA “Control”	IIIB “Cooled”	IIIC “On/Off”	NA

Table-1: Study Distribution

Polymerization temperature rise (°C)	Matrix Material						P-value (Inter-Group)		
	Group I (Vacuum form template) (n=40)		Group II (PVS putty index) (n=30)		Group III (Alginate impression index) (n=30)		Group I v Group II	Group I v Group III	Group II v Group III
Cooling Technique	Mean	SD	Mean	SD	Mean	SD			
Control (n=10)	12.47	0.12	9.15	0.07	7.78	0.09	0.001***	0.001***	0.001***
Removal/Cooled (n=10)	7.56	0.11	4.64	0.08	1.67	0.09	0.001***	0.001***	0.001***
On/Off (n=10)	8.72	0.08	5.55	0.07	4.17	0.08	0.001***	0.001***	0.001***
In situ (n=10)	10.11	0.07	--	--	--	--	--	--	--
Overall	9.71	1.85	6.45	1.98	4.54	2.55	0.001***	0.001***	0.001***

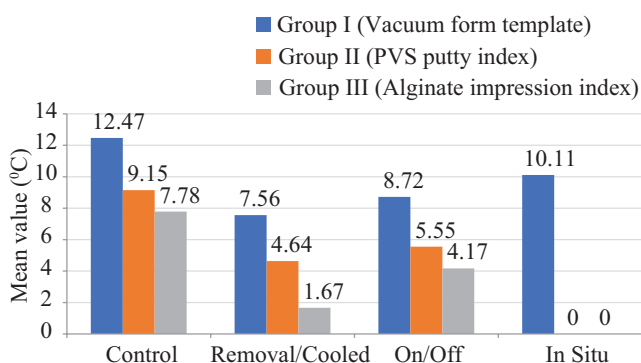
P-value by one-way analysis of variance (ANOVA) with Bonferroni's correction for multiple group comparisons. P-value<0.05 is considered to be statistically significant. ***P-value<0.001.

Table-2: Inter matrix material group comparison of mean polymerization temperature rise.

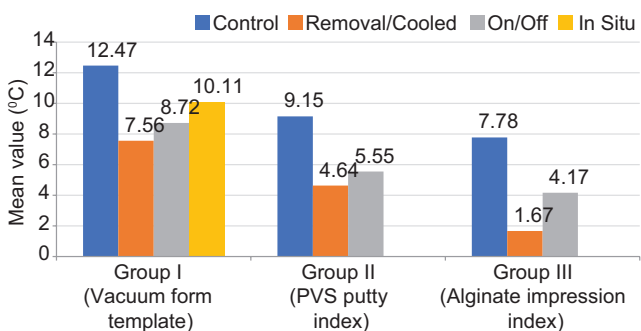
Polymerization temperature rise (°C)	Matrix Material					
	Group I (Vacuum form template) (n=40)		Group II (PVS putty index) (n=30)		Group III (Alginate impression index) (n=30)	
Cooling Technique	Mean	SD	Mean	SD	Mean	SD
Control (n=10)	12.47	0.12	9.15	0.07	7.78	0.09
Removal/Cooled (n=10)	7.56	0.11	4.64	0.08	1.67	0.09
On/Off (n=10)	8.72	0.08	5.55	0.07	4.17	0.08
In situ (n=10)	10.11	0.07	--	--	--	--
P-value (Intra-Group)						
Control v Removal/Cooled	0.001***		0.001***		0.001***	
Control v On/Off	0.001***		0.001***		0.001***	
Control v In Situ	0.001***		--		--	
Removal/Cooled v On/Off	0.001***		0.001***		0.001***	
Removal/Cooled v In Situ	0.001***		--		--	
On/Off v In Situ	0.001***		--		--	

P-value by one-way analysis of variance (ANOVA) with Bonferroni's correction for multiple group comparisons. P-value<0.05 is considered to be statistically significant. ***P-value<0.001.

Table-3: Intra group (Inter-cooling techniques) comparison of mean polymerization temperature rise in each matrix material group.



Graph-1: Inter matrix material group comparison of mean polymerization temperature rise.



Graph-2: Intra matrix material group comparison of mean polymerization temperature rise

tested before subjecting each variable to t-test and ANOVA. All the results are shown in tabular as well as graphical format to visualize the statistically significant difference more clearly.

In the entire study, the p-values less than 0.05 are considered to be statistically significant. All the hypotheses were formulated using two tailed alternatives against each null hypothesis (hypothesis of no difference). The entire data was statistically analyzed using Statistical Package for Social Sciences (SPSS ver 21.0, IBM Corporation, USA) for MS Windows.

Inter-Matrix Material Group Comparisons (Table: 2)

Distribution of mean Polymerization temperature rise is

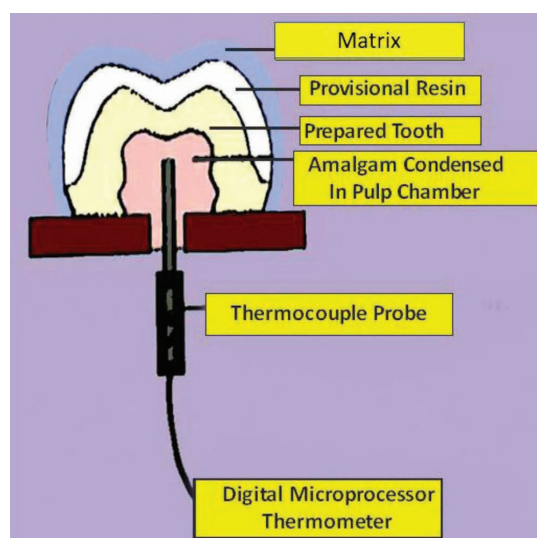


Figure-1: Schematic Representation of Test Model

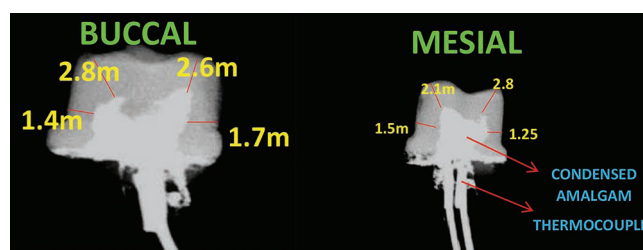


Figure-2: RVG Evaluation of Tooth Model

significantly higher in Group I compared to Groups II and III in control as well as all cooling techniques (P-value<0.001 for both). It is thus concluded that the best matrix material that caused least temperature rise is Alginate impression matrix followed by PVS putty index and vacuum form template (Graph 1). The following was the order of heat dissipation for the different matrices used:

Irreversible hydrocolloid matrix > PVS putty matrix > vacuum form template

Intra-Matrix Material Group (Inter-Cooling Technique Groups) Comparisons (Table: 3)

Distribution of mean Polymerization temperature rise was

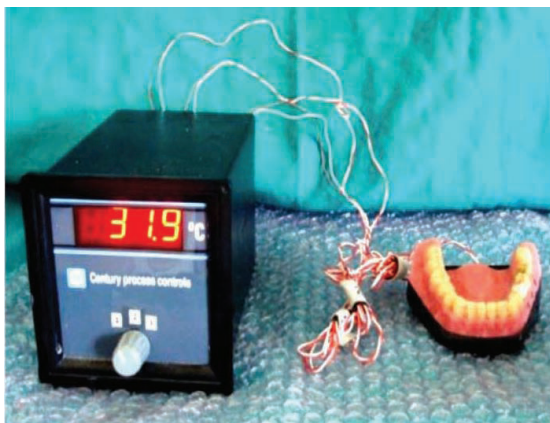


Figure-3: Study Model

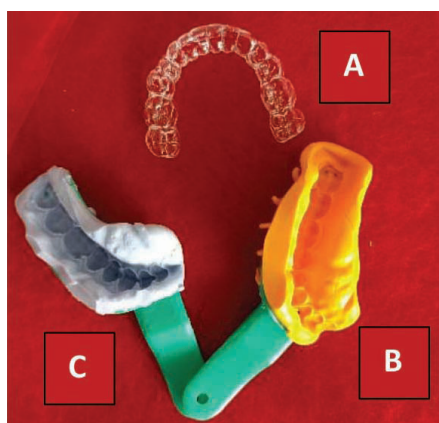


Figure-4: Matrices Used (A) Vacuum Formed Template (B) Putty Index (C) Alginate Index

significantly higher in Control Cooling group compared to Removal/Cooled, On/Off and In-Situ Cooling groups (P -value <0.001 for all). Distribution of mean Polymerization temperature rise is significantly higher in In-Situ Cooling group compared to Removal/Cooled and On/Off Cooling groups (P -value <0.001 for all). Distribution of mean Polymerization temperature rise is significantly higher in On/Off Cooling group compared to Removal/Cooled Cooling groups (P -value <0.001).

In Group II (PVS putty index)

Distribution of mean Polymerization temperature rise is significantly higher in Control Cooling group compared to Removal/Cooled and On/Off Cooling groups (P -value <0.001 for both). Distribution of mean Polymerization temperature rise is significantly higher in On/Off Cooling group compared to Cooled Cooling groups (P -value <0.001).

In Group III (Alginate impression index)

Distribution of mean Polymerization temperature rise is significantly higher in Control Cooling group compared to Removal/Cooled and On/Off Cooling groups (P -value <0.001 for both). Distribution of mean Polymerization temperature rise is significantly higher in On/Off Cooling group compared to /Cooled Cooling groups (P -value <0.001).

Intragroup Comparison showed following results (Graph 2) “Control” sub-group showed 2-3 times rise in the intrapulpal temperature than other three cooling techniques used.

For the PVS putty index (group II), “cooled” index showed almost half the intrapulpal temperature rise when compared

to the “control” group.

For the alginate index (group III) “cooled” index showed almost 1/5th intrapulpal temperature rise when compared to the “control” subgroup

“Cooled” polyvinyl siloxane putty index and irreversible hydrocolloid (alginate) index can act as a heat sink for heat of polymerization of provisional resin.

It is thus concluded that the best cooling technique that caused least temperature rise is using “Cooled” alginate or putty as matrix system followed by “On/Off” technique. For Vacuum formed template “Removal” technique was most effective followed by “On/Off” and least effective was “In Situ” technique.

DISCUSSION

The temperature rise during setting reaction of provisional restoration was explained by Driscoll et al (1991)¹⁸ based on chemical reaction of the polymer based provisional materials. As the polymerization proceeds, the carbon-carbon double bonds (pi-bonds) are converted to new carbon-carbon single bond (sigma-bonds). The carbon-carbon sigma-bonds have energy of about 270kj/mol and carbon-carbon pi bonds have 350kj/mol. The difference in the energy between the two bonds, 80kj/ mol, is emitted as exothermic heat. This quantum of heat if not controlled may cause thermal damage to the pulp.

Pulpal injury can result from exothermic setting reaction of temporization material. Zach and Cohen (1965) showed that an intrapulpal temperature rise of 5.5°C (10°F) in rhesus mecaca monkey caused 15% of the pulp to loose vitality.¹⁶ 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, expansion of liquid in the dentinal tubules and vascular injuries with generalized or localized tissue necrosis, resulting in acute inflammation of pulp, irreversible pulpitis, or pulp necrosis in severe cases.^{13,14,16}

Biologically acceptable fixed prosthodontic treatment demands that prepared teeth be protected and stabilized with provisional restorations that resemble the form and function of the planned definitive restorations.¹⁰ There are two principal methods in fabrication of provisional restorations i.e. direct and indirect.¹² Direct method of provisionalization is fast and economical. There is reduction in an extra clinical appointment both for the dentist and the patient.^{10,12}

The heat transferred to the tooth is greatly reduced by the choice of matrix used to hold the provisional material. Moulding and Loney (1991)¹⁷ evaluated the efficacy of 3 cooling techniques 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 “3 cooling techniques were equally effective” in preventing the thermal damage to pulp. Hence, this study was undertaken to relatively compare the effectiveness of different cooling techniques in minimizing the heat transfer to the pulp during direct fabrication of provisional restorations.

A test model that closely resembled the intraoral conditions was fabricated. Although the model was similar, there were following differences. Silver amalgam replaced the pulpal tissue, and therefore the amount of heat required to produce a given increase in the test model was little than that needed

for a pulpal tissue increase because of the greater density and volume of amalgam present. However, the amalgam transmitted heat from all surfaces of the pulpal and dentin interface and may be a more accurate method of comparing heat transmission than the single-point thermocouple method. Gingiva and bone were replaced by resin in the model. In clinical condition, the elevation in temperature is also reduced by presence of the periodontal ligament⁵ and other organic structures, such as gingiva, protoplasmic extension of cells in dentinal tubules.² Pulpal and osseous circulation are also effective in heat dissipation.¹² The investigation was conducted at a controlled ambient temperature for ease and uniformity. Minor ambient temperature difference may have affected the resultant net temperature rise for a given amount of energy dissipation, but its effect would likely to be small. Although, these differences did exist, a comparative analysis between method of cooling techniques during provisionalization was possible.

The following was the order in heat dissipation for the different matrices used: Irreversible hydrocolloid matrix > PVS putty matrix > vacuum form template.

For all combinations used, the "cooled" alginate index produced the least intrapulpal temperature rise and vacuum form template produced the maximum temperature rise.

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 0.0015°C/cm.⁷ Damage to vital cells can occur even though the thermocouple records no significant rise in temperature.¹¹ The residual dentin thickness was determined in present model by using digital radiography (Dexes Software) (photograph-8). It ranged from 1.4mm to 2.8mm (Fig 3). 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 tooth model was 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.^{20,23}

$$H = \frac{KA(t_2 - t_1)}{D}$$

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.⁴

Also, teeth may have a large metal restoration that is more conductive thermally than the tooth structure e.g. amalgam restoration²¹ which has a high thermal conductivity of 22.6 Wm⁻¹k⁻¹. Such a restoration would result in a greater increase in intrapulpal temperature during direct fabrication of temporary restorations. Wear, attrition, erosion, caries may affect both quality and quantity of the remaining dentin thickness.²² For this study, non-carious teeth with

no restoration were selected to decrease variability and to determine if temporary fabrication under ideal circumstances. Other factors to be considered are bulk of the acrylic resin, monomer / polymer ratios, type of resin used in fabricating provisionals. Moulding and Teplitzky (1991)¹⁹ found a statistically significant differences in temperature rise in pulp between the single-unit and fixed partial denture. Polymethyl methacrylate (PMMA) has been reported to produce a greater pulpal temperature rise than other available resins.^{16,19,20,25} Therefore, PMMA was used in this study to get a significant temperature rise for comparison.

Due to the number of variables involved, it would appear difficult to determine an actual temperature rise for a given tooth in a clinical situation. Nonetheless, the data from the present study allow clinicians to select a technique based on relative cooling effectiveness.

Whenever several teeth are prepared and no significant undercuts are present, it is recommended to use "cooled" alginate index as matrix for fabricating the provisional restoration. If there are large undercuts in adjacent teeth, the "removal" or "on/off" technique might be preferable to the "in situ" cooling technique to prevent the restoration from locking into adjacent undercut.

Clinician should make all efforts to minimize potential iatrogenic insult to the pulp during fabrication of provisional restorations with direct technique. It is recommended to use low exotherm provisional restorative materials and different cooling techniques as adjuncts to reduce thermal damage to pulp.

CONCLUSION

An ex-vivo study was conducted to evaluate the relative efficacy of cooling techniques on intrapulpal temperature during direct fabrication of provisional restoration. The findings from the study can be summarised as follows:

The highest intrapulpal temperature rise was recorded when a vacuum form template was. The lowest intrapulpal temperature was recorded when an alginate index. The order of heat dissipation for the different matrices used was in following order:

Irreversible hydrocolloid matrix > PVS putty matrix > vacuum form template

"Cooling" of PVS putty and alginate impression index for 2 minutes in refrigerator (Ambient temperature 10-12°C) is the most effective "cooling" method for preventing temperature rise in pulp followed by "On/Off" technique.

Further it is suggested, that for direct provisionalization of long span fixed dental prosthesis where possibility of temperature rise is higher, cooled alginate and putty index may be technique of choice to prevent thermal insult to the pulpal tissues.

Use of Vacuum formed template as a matrix material should be done with caution and restricted to provisional materials with least exothermic properties like Bis acrylic composites or light curable provisional materials.

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