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Original Article

Intrapulpal thermal changes during direct provisionalization using various autopolymerizing resins: Ex-vivo study

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ARTICLE INFO

Article history:

Received 17 September 2012

Accepted 1 February 2013

Available online 11 July 2013

Keywords:

Thermal Changes

Pulp chamber

Provisionalization

Autopolymerizing resins

Abutment preparations

Remaining dentine thickness

ABSTRACT

Background: Resin materials used in the fabrication of direct provisional restoration exhibit an exothermic reaction and the extent of damage may also depend on the remaining dentine thickness. An ex-vivo study was envisaged to compare the time related temperature changes in the pulp chamber during the fabrication of fixed partial denture provisional restorations using direct technique. The effect of differently prepared teeth (with varying remaining dentine thickness) on the above mentioned temperature changes were also evaluated.

Methods: Thermal changes were calculated in pulp chamber of three differently prepared tooth having different amount of remaining dentinal thickness (45 samples) and control with no tooth media (15 samples), using three different types of autopolymerizing provisional restorative materials using Cr/Al thermocouple connected to digital thermometer.

Results: The data for the mean peak temperature rise was subjected to one way ANOVA analysis for relative comparison among subgroups within each main group and across the main groups. The results showed a statistically significant difference across both the subgroups and the main groups ($p < 0.001$). Then Turkey HSD test was applied to determine the significance of statistical difference between the means, within the groups. The differences in temperature rise were statistically significant for the three resins ($p < 0.001$). **Conclusion:** Polymethylmethacrylate (DPI) showed the highest temperature rise value followed by polyethyl methacrylate (Tempron) and Bis-acrylate composite (CoolTemp). The maximum temperature rise was found on molar full veneer preparation followed by molar three quarter preparation and premolar three quarter preparation. Data and results from current study may assist clinicians to select an autopolymerizing provisional restorative resin when employing direct technique of fabricating provisional restorations for a specific tooth preparation which would cause minimal thermal trauma to pulpal tissue.

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<http://dx.doi.org/10.1016/j.mjafi.2013.02.005>

Introduction

Fabrication of a successful crown or fixed partial denture requires the precise execution of many steps, from the initial visit for data collection and diagnosis through the post insertion visits. One of the intermediate steps is the fabrication of the interim prosthesis.¹ An interim/provisional prosthesis is defined as “a fixed or removable dental prosthesis or maxillofacial prosthesis, designed to enhance esthetics, stabilization and/or function for a limited period of time, after which it is to be replaced by a definitive dental or maxillofacial prosthesis (GPT-8).”²

The fabrication of provisional restoration is a necessary procedure following extra coronal tooth preparation until the definitive prosthesis is placed.³ The requirements of a provisional restoration are to provide pulpal protection, positional stability, maintenance of occlusal function, with minimal damage to tooth and supporting structures.^{4–10} One of the important requirements of the temporization material is that it should be non irritating to pulp and other tissues i.e. should have low exothermicity. The most common materials employed for custom provisional fixed restorations are acrylic resins. Several types of acrylic resin materials are available for provisional restoration fabrication, 5, 9: polymethyl methacrylate resins, polyethyl methacrylate resins, Bis-acrylate composites & other types or combinations of unfilled methacrylate resins.

There are **direct** (provisional restoration fabricated directly on the prepared teeth in the patient's mouth) and **indirect** (provisional restoration fabricated on the stone cast) ways of fabricating these restorations. The indirect method has been associated with superior fit^{11,12} and pulp protection but its disadvantage is that an intermediate impression and stone cast are required to fabricate the provisional restoration. On the contrary direct provisional restoration fabrication method efficiently uses time and materials, and also inadequate or absence of in-house lab support has led to its continued use.^{13,14} One of the disadvantages of direct method is the exposure of the tooth structure (pulp through remaining dentinal thickness) to the heat produced by polymerization of polymer based temporization materials (Grajower R et al, 1979).¹⁵

Probability of pulpal damage is more when the temperature increase exceeds the physiologic heat dissipation mechanisms of the dental periodontal system. Mechanisms of injury include protoplasm coagulation, expansion of the liquid in the dentinal tubules and pulp with increased outward flow from the tubules, vascular injuries and tissue necrosis.^{16,17} According to Zach and Cohen (1965),¹⁸ a temperature rise of 5.5 °C can lead to 15% loss of vitality in the pulp, an 11 °C rise causes about 60% and a 16.6 °C temperature rise causes 100% necrosis of the pulp.

The thickness of dentinal tissues remaining after the abutment preparations plays an important role as it affects the quantum of heat transferred to the pulp chamber during direct provisionalization.^{19,20} Keeping this in view the present study was envisaged. An ex-vivo study was conducted to compare the temperature rise in the pulp chamber during direct provisionalization using various autopolymerizing resins and also to evaluate the effect of residual dentinal thickness of differently prepared teeth on the above mentioned temperature rise.

Materials and methodology

The study was divided into three main groups on the basis of provisional materials (Table 1; Fig. 5) and further sub divided into three subgroups on the basis of tooth preparation; each sub group had five readings. Making a total of 45 samples.

Study model was fabricated by replicating mandibular typodont model using autopolymerizing acrylic resin (tooth coloured and pink acrylic were used for demarcation of tooth area). Area 35, 36 & 37 of acrylic model was trimmed till base 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 teeth numbers 35, 36 and 37 of an average size and form.¹⁹ The mandibular second molar (37) was prepared to receive conventional three quarter crown mandibular second premolar (35) was prepared to receive conventional three quarter crown mandibular first molar (36) was prepared to receive conventional complete veneer metal crown. The roots of these extracted prepared teeth were sectioned 3 mm below cemento-enamel junction

Table 1 – Intergroup comparison of mean peak temperature achieved for different samples.

S. no.	Sample	Group	Mean	SD	F	p
1.	Control	Bis-acrylate composite (5)	13.76	0.15	6497.32	<0.001
		PEMA (5)	16.14	0.15		
		PMMA (5)	23.46	0.11		
2.	Premolar $\frac{3}{4}$ preparation	Bis-acrylate composite (5)	6.86	0.11	7899.88	<0.001
		PEMA (5)	6.98	0.08		
		PMMA (5)	14.14	0.11		
3.	Molar $\frac{3}{4}$ preparation	Bis-acrylate composite (5)	8.72	0.11	3753.63	<0.001
		PEMA (5)	10.76	0.13		
		PMMA (5)	15.14	0.11		
4.	Molar full veneer preparation	Bis-acrylate composite (5)	10.04	0.15	6370.54	<0.001
		PEMA (5)	12.02	0.08		
		PMMA (5)	18.66	0.13		

Temperature rise for various specimen in different groups.

using a diamond disc. After proper cleaning of the pulp chamber the thermocouple probes (Cr/Al type, 1 mm diameter) were positioned inside the pulp chambers of 35, 36 & 37 and silver amalgam condensed around the probe, filling the pulp chamber. Finally, the orifice & probes was secured using glass-ionomer cement material. The proper positioning of the thermocouple inside the abutment teeth was ascertained through radiovisiography. Also RVG radiographic technique was used to note the remaining dentine thickness (RDT) of

prepared abutments (Fig. 1). The teeth were then placed in their respective positions in mandibular acrylic model (space earlier prepared). The thermocouple lead wires were attached to the digital thermometer which was duly calibrated (Fig. 2).

Wax patterns were then fabricated over prepared teeth to make space for provisional restorative material. Thickness of wax patterns was standardized to 1 mm (to standardize the quantity of provisional material) (Fig. 3). Negative replica of the above model was made using additional silicone

Fig. 1 – RVG showing differently prepared tooth with varying RDT and thermocouple probe placement.

Fig. 2 – Final test model (Study model).

impression material to which die stone was poured, the die stone replica thus obtained was used to form vacuum formed templates which were used as a matrix to carry provisional restorative material (Fig. 4).

Recording of thermal changes in the pulp chamber during provisionalization was done using three common types of autopolymerizing tooth coloured material (Fig. 5) as follows: PMMA (DPI Lot 980515), PEMA (Tempron Lot 0803261) & Bis-acrylate composite (CoolTemp Lot B008C068). Recording of temperature change was done 5 s interval.

Control for the study was planned with no tooth media between thermocouple and setting provisional material. Study was divided into three groups on the basis of provisional materials each groups having 5 samples. Making a total of 15 samples. Study model for control was fabricated using a typodont molar (36) so as to mimic the total volume of natural tooth. Die stone replica was then used for fabricating vacuum matrix template (1 mm thick) (Fig. 6). Silver coping of blank 1.5 mm was used to cover the thermocouple so as to protect it from setting provisional resins. The thermocouple was placed in the silver copings and silver amalgam was condensed around it and finally sealed using GIC. Recording of control was done by lubricating the silver coping with a single layer of petroleum jelly (separating medium) following which the copings were placed in the centre of the loaded matrix and readings were recorded as shown on digital thermometer at an interval of 5 s (Fig. 7). A constant ambient temperature of 28°C was constantly maintained in the air-conditioned lab. The room temperature

Fig. 3 – Wax patterns on prepared teeth with thickness 1 mm.

Fig. 4 – Die stone model and vacuum form templates (matrix material).

was continuously monitored. Intrapulpal thermal variations & time related thermal changes of provisional materials were recorded tabulated and statistically analysed.

Results

The data for the mean peak temperature rise was subjected to one way ANOVA analysis to make relative comparison among the subgroups (type of tooth preparation and control) within each main group (type of material) and across the main groups. The results showed a statistically significant difference across both the subgroups and the main groups ($p < 0.001$) (Table 1). Following the detection of statistical significant difference the Turkey HSD test was applied to determine the significance of statistical difference between the means, within the groups i.e. intergroup comparison. The differences in temperature rise were statistically significant for the three resins ($p < 0.001$).

For maximum temperature range (i.e. $>16.5^\circ\text{C}$), amongst control specimen no difference in mean time was seen between Bis-acrylate composite (CoolTemp) and PEMA (Tempron) while PMMA (DPI) had significantly higher mean time as compared to both Bis-acrylate composite (CoolTemp) as well as PEMA (Tempron) ($p < 0.001$).

Fig. 5 – Test materials used in study.

Fig. 6 – Typodont used and Diestone replica.

None of the specimens in premolar $\frac{3}{4}$ preparation and molar $\frac{3}{4}$ preparation reached to this temperature while in molar full veneer preparation specimen, only specimen of PMMA (DPI) group reached to this temperature.

Temperature rise and specimen type

Temperature rise $>16.65^{\circ}\text{C}$ was maximum in control specimen followed by full veneer while $<5.5^{\circ}\text{C}$ was most common amongst premolar $\frac{3}{4}$ preparation specimen. None of the specimen of premolar $\frac{3}{4}$ and molar $\frac{3}{4}$ had temperature rise $>16.65^{\circ}\text{C}$ (Graph 1).

Temperature rise for various specimen in different groups

As could be seen through Table 2 & Graph 2–6. It was maximum for control followed by molar full veneer, 3/4th preparation on molar and 3/4th preparation on premolar, in that order. The graph also shows that there were significant differences in peak temperature rise for different materials

Fig. 7 – Silver coping placed over thermocouple probe and Schematic diagram of Test model (Control).

Graph 1 – Mean time vs temp rise in various specimen.

too. On the basis of above findings the peak temperature rise for different materials was as follows: PMMA (DPI) $>$ PEMA (Tempron) $>$ Bis-acrylate composite (CoolTemp). Further the combination of tooth preparation material that showed maximum temperature rise was of PMMA + full veneer Crown ($>16.5^{\circ}\text{C}$) & minimum was Bis-acrylate composite + premolar $\frac{3}{4}$ ($<5.5^{\circ}\text{C}$).

Discussion

The differences in temperature rise were statistically significant for the three resins ($p < 0.001$). The intrapulpal temperature rise was greatest with PMMA (DPI) followed by PEMA (Tempron) and Bis-acryl (CoolTemp). The result of the present study is in agreement with the findings of previous study done by Tjan et al (1989)²⁰ & another recent study by Michalakakis et al (2006)²¹ which investigated the effect of various autopolymerizing resins on temperature rise during the fabrication of direct provisional restoration.

Driscoll et al (1991)²², provided an explanation for the observed temperature rise during setting of provisional restoration. The chemical reaction of the polymer based provisional materials is an addition polymerization. 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 270 kJ/mol and carbon-carbon pi bonds have 350 kJ/mol. The difference in the energy between the two bonds, 80 kJ/mol, is emitted as exothermic heat. In industries, the large heat emission during polymerization can cause serious problems such as rapid reactions, which lead to thermal explosions. In dentistry, it may cause thermal damage to the pulp.

All the three resins exhibited exothermic behaviour in the study. But, PMMA (DPI) showed the highest mean temperature rise followed by PEMA (Tempron) and Bis-acrylate composite resin (CoolTemp). This can be explained by the fact that the chemical composition of acrylic resin affects the peak temperature at the time of polymerization (Graph 1 and 2).

Statistical analysis of the effect of various preparation designs (remaining dentine thickness) on time related temperature rise in the pulp showed statistically significant

Table 2 – Comparison of mean peak temperature rise in for different specimen in different groups.

S. no.	Specimen	N	CoolTemp		PEMA		PMMA	
			Mean	SD	Mean	SD	Mean	SD
1.	Control	5	13.76	0.15	16.14	0.15	23.46	0.11
2.	Premolar $\frac{3}{4}$ preparation	5	6.86	0.11	6.98	0.08	14.14	0.11
3.	Molar $\frac{3}{4}$ preparation	5	8.72	0.11	10.76	0.13	15.14	0.11
4.	Molar full veneer preparation	5	10.04	0.15	12.02	0.08	18.66	0.13
F (ANOVA)			2398.225		5184.909		6226.80	
"p"			<0.001		<0.001		<0.001	

difference in mean peak temperature rise ($p < 0.001$). It was maximum for full veneer preparation on molar, followed by 3/4th preparation on molar and 3/4th preparation on premolar. Thus suggesting the effect of remaining dentine thickness on intrapulpal temperature rise which is in agreement with the previous study done by Altintas et al in 2007¹⁹ who studied the effect of remaining dentine thickness on the net temperature rise in the pulp chamber during fabrication of direct provisional restoration using dentine disc of varying thickness (1.2 mm) and found that temperature rise was more when the dentinal thickness was reduced (as in deep cavity preparations). Thus when choosing a provisional restorative material or technique it is important to consider the type of preparation as a material may be harmless in one design and may be lethal for others.

According to a histological study conducted by Zach and Cohen¹⁸ in the year 1965 which showed that a temperature rise of 5.6 °C can lead to 15% loss of vitality in the pulp, a 11 °C temperature rise about 60% and a 16.6 °C temperature rise causes 100% necrosis of the pulp. In the current study the time related temperature rise was analysed for each preparation under each group. Further the total temperature rise was divided in four main categories i.e upto 5.5 °C, 5.5 °C–11 °C, 11 °C–16.5 °C and above 16.5 °C. This categorization was affected to evaluate the time for which different temperature categories were maintained by groups and subgroup, thus giving an incidence of thermal insult caused to the pulp during the use of a particular material and preparation design. Statistical analysis (Table 2; Graph 2) showed that Bis-acrylate composite (CoolTemp) and PEMA (Tempron) had significantly

lower mean time at higher temperatures as compared to PMMA (DPI). Further, Bis-acrylate composite elicited maximum mean time at lower temperature, amongst the test provisional restorative materials. The analysis also revealed the effect of various preparations on temperature rise value. In greater than (>) 16.65 °C category, maximum readings were for full veneer preparation on molar specimen while less than equal to (<) 5.5 °C was most common amongst 3/4th preparation on premolar specimen. None of the specimen of 3/4th preparation on premolar and 3/4th preparation on molar had temperature rise greater than (>) 16.65 °C. The time related temperature graph of various materials (Graphs 1 and 2) showed that Bis-acrylate composite (CoolTemp) had fastest rise and fall of temperature suggesting lower working time and setting time while PEMA (Tempron) had slowest rise and fall suggesting longer working time and setting time.

Thus the procedures which need to be completed in shorter duration can be successfully carried out using Bis-acryl composite (CoolTemp) while procedures that have to be performed in longer duration the material suitable are PEMA (Tempron) and PMMA (DPI) respectively.

Grajower et al (1979)¹⁵ found a 15% reduction in intrapulpal temperature rise when simulated pulpal blood flow of 0.1 cc/minute was used in teeth. Pulp tissue is encased in a hard tissue and has a limited blood supply. Anderson (1994)²³ demonstrated that increasing intrapulpal temperature does not result in increased pulpal blood flow. Hence, the pulp which may already be bearing the brunt of thermal changes from tooth preparation and previous inflammatory changes

Graph 2 – Comparison of mean peak temp rise for different specimen in different groups. **Graph 3 – Pictorial summary of behaviour of different materials under different conditions control specimen.**

Graph 4 – Pictorial summary of behaviour of different materials under different conditions. Premolar $3/4$ preparation.

may cause the pulpal tissue to compromise with limited perfusion.

Also, teeth may have large metal restorations that is more conductive thermally than the tooth structure e.g. amalgam restoration²⁴ which has a high thermal conductivity of $22.6 \text{ W m}^{-1} \text{ K}^{-1}$. Such a restoration would result in a greater increase in intrapulpal temperature and thus more thermal insult during direct fabrication of temporary restorations. Wear, attrition, erosion, caries may affect both quality and quantity of the remaining dent in thickness.

Because of 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 current study may assist clinicians to select an autopolymerizing provisional restorative resin when employing direct technique of fabricating provisional restorations for a specific tooth preparation.

If fabrication of provisional restorations by direct technique is opted, precautionary measures must be adopted to minimize temperature increase of the tooth structure from the exothermic reaction of the resins. The temperature rise

Graph 5 – Pictorial summary of behaviour of different materials under different conditions. Molar full veneer specimen.

Graph 6 – Pictorial summary of behaviour of different materials under different conditions. Molar $3/4$ specimen.

may be reduced by employing various cooling techniques like removing the provisional restoration after the initial polymerization of resin; using air/water spray etc²⁵.

Since the amount of heat generated is proportional to the volume of material used, for multiple interim crowns or complex fixed partial dentures with multiple pontics, the indirect technique is best indicated for such cases. The direct technique is well suited for single crown short span (up to three units) units & endodontically treated teeth. Hence, efforts should be made to minimize potential iatrogenic insult to teeth during fabrication of provisional restorations.

Conclusion

Temperature elevations in the pulpal chambers during fabrication of provisional resinous crowns by the direct method were recorded ex-vivo.

- (1) The type of autopolymerizing provisional restorative resin used during fabrication of provisional restoration by direct technique affects the intrapulpal temperature rise. Polymethylmethacrylate (DPI) showed the highest temperature rise value followed by polyethyl methacrylate (Tempron) and Bis-acrylate composite (CoolTemp).
- (2) Intrapulpal temperature rise also varies in relation to the type of preparation. The maximum temperature rise was found in full veneer preparation on molar followed by three quarter ($3/4$ th) preparation on molar and three quarter ($3/4$ th) preparation on premolar. Thus, suggesting the thermal insulating effect of remaining dentine thickness. Polymethylmethacrylate (DPI) used on full veneer preparation on molar in the study caused maximum temperature elevation, reaching above 16.5°C i.e. $18.66 \pm 0.13^\circ\text{C}$ which is indicative of 100% incidence of total pulp death. Thus, this combination of resin and tooth preparation (with minimal RDT) should be avoided.
- (3) Among the materials tested in the study the resin material recommended for clinical use when direct technique is employed for fabrication of provisional restorations, is Bis-

acryl composite resin (CoolTemp) as it caused minimal temperature rise in the pulp chamber. The time duration that experienced the peak temperature was least in case of Bis-acrylate composite (CoolTemp), thus implying that the time of thermal insult to pulp tissue was minimal in case of Bis-acrylate composite (CoolTemp). It may be suggested that Bis-acrylate composite (CoolTemp) may be thermally least harmful to the pulp tissue as compared to PEMA (Tempron) and PMMA (DPI).

- (4) Further, it is suggested that the procedures requiring shorter working duration can be successfully carried out using Bis-acryl (CoolTemp) due to its shorter working & setting time. While for the procedures that require longer working time, the provisional materials best suited are PEMA (Tempron) followed by PMMA (DPI). PMMA (DPI) should be used cautiously for direct provisionalization on a vital tooth.

Conflicts of interest

All authors have none to declare.

Acknowledgement

With profound regard we convey our heartfelt gratitude to our respected teacher Late Lt Gen (Dr.) R.C. Dhir PVSM, for his teachings and guidance.

REFERENCES

1. Fedrick DR. The provisional fixed partial denture. *J Prosthet Dent*. 1975 Nov;34(5):520–526.
2. The glossary of prosthodontic terms. *J Prosthet Dent*. 2005;94(1):10–92.
3. Shillingburg H, Jacobi R, Brackett SE. *Fundamentals of Fixed Prosthodontics*. 3rd ed. Quintessence Publishing Co; 1997:225–256.
4. Burns DR, Beck DA, Nelson SK. A review of selected dental literature on contemporary provisional fixed prosthodontic treatment: report of the committee on research in FPD of the Academy of Fixed Prosthodontics. *J Prosthet Dent*. 2003;90:474–497.
5. Gratton DG, Aquilino SA. Interim restorations. *Dent Clin North Am*. 2004;487–497.
6. Hunter RN. Construction of accurate acrylic resin provisional restorations. *J Prosthet Dent*. 1983;50(4):520–521.
7. Lieu C, Nguyen TM, Payant L. In vitro comparison of peak polymerization temperatures of 5 provisional restoration resins. *J Cant Dent Assoc*. 2001;67:36–39.
8. Sotera AJ. A direct technique for fabricating acrylic resin temporary crowns using the Omnivac. *J Prosthet Dent*. 1973;29(5):577–580.
9. Vahidi F. The provisional restoration. *Dent Clin North Am*. 1987;31:363–381.
10. Baldissara P, Comin G, Martone F, Scotti R. Comparative study of the marginal microleakage of six cements in fixed provisional crowns. *J Prosthet Dent*. 1998;80:417–422.
11. Crispin BJ, Caputo AA. The marginal accuracy of treatment restorations: a comparative analysis. *J Prosthet Dent*. 1980;44:283–290.
12. Monday JJ, Blais D. Marginal adaptation of provisional acrylic resin crowns. *J Prosthet Dent*. 1985;54:194–197.
13. Robinson FB. Hovijitras: marginal integrity of direct temporary crowns. *J Prosthet Dent*. 1982;47:390–392.
14. Wang RL, Moore BK, Goodacre CJ, Swartz ML, Andres CJ. A comparison of resins for fabricating provisional fixed restorations. *Int J Prosthodont*. 1989;2:173–184.
15. Grajower R, Shaharabani S, Kaufman E. Temperature rise in pulp chamber during fabrication of temporary self-curing resin crowns. *J Prosthet Dent*. 1979;41(5):535–540.
16. Nyborg H, Brannstrom M. Pulp reaction to heat. *J Prosthet Dent*. 1968;19(6):605–612.
17. Stanley HR. Pulpal response to dental techniques and materials. *Dent Clin North Am*. 1971;15(1):115–126.
18. Zach L, Cohen G. Pulp response to externally applied heat. *Oral Surg Oral Med Oral Path*. 1965;19:515–530.
19. Altintas SH, Yondem I, Tak O, Usumez A. Temperature rise during polymerization of three different provisional materials. *Clin Oral Investig*. 2007;12(3):283–286.
20. Tjan AHL, Grant BE, Godfrey MF. Temperature rise in the pulp chamber during fabrication of provisional crowns. *J Prosthet Dent*. 1989;62:622–626.
21. Driscoll CF, Woolsey G, Ferguson WM. Comparison of exothermic release during polymerization of four materials used to fabricate interim restoration. *J Prosthet Dent*. 1991;65:504–506.
22. Moulding MB, Loney RW. The effect of cooling techniques on intra pulpal temperature during direct fabrication of provisional restorations. *Int J Prosthodont*. 1991;4:332–336.
23. Michalkis 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 Prosthet Dent*. 2006;96:418–423.
24. Andersen E, Aars H, Brodin P. Effects of cooling and heating of the tooth on pulpal blood flow in man. *Endod Dent Traumatol*. 1994;10:256–259.
25. Anusavice KJ. *Phillips' Science of Dental Materials*. 11th ed. Saunders:239–248.