ACP
AMERICAN COLLEGE OF PROSTHODONTISTS

Intrapulpal Heat Generation during Provisionalization: Effect of Desensitizer and Matrix Type

Tolga Akova, DDS, PhD, Ahmet Ozkomur, DDS, Cengiz Dundar, DDS & Neslin Aytutuldu, DDS

Department of Prosthodontics, Faculty of Dentistry, Cukurova University, Balcali, Adana, Turkey

Keywords
Pulpal damage; provisional restorations; intrapulpal heat generation; thermocouple.

Correspondence
Tolga Akova, Çukurova Üniversitesi, Diş Hekimliği Fakültesi, 01330 Balcal, Adana, Turkey. E-mail: akovat@cu.edu.tr

Presented at the Joint Meeting of the Continental European Division (CED) and the Scandinavian Division (NOF) of the IADR, Amsterdam; September 14–17, 2005.

Accepted August 21, 2006

doi: 10.1111/j.1532-849X.2007.00257.x

Abstract

Purpose: This study investigated the effect of different matrices and application of a desensitizer on pulpal temperature rise during direct provisionalization.
Materials and Methods: The apical third of a second premolar was resected and pulpal tissue was removed. Silicone heat-conducting medium was injected, and a J-type thermocouple was inserted into the pulp chamber and sealed. The tooth was embedded in acrylic resin with its cervical line 1 mm higher than the base. Addition and condensation silicone impression materials were mixed and placed inside plastic molds. Impressions were taken before tooth preparation. The tooth was then prepared with a 1.5-mm shoulder finish line. The experimental model was kept in a 36 °C water bath. Four provisional materials were applied in sequence onto the prepared tooth using matrices. Each provisional resin was used in combination with each matrix (n = 12). Then a dentin desensitizer was coated on the prepared tooth and provisionalizations were made in the same manner. The thermocouple was connected to the data-logger. During setting of the resins, pulp temperatures were recorded and transferred to the computer. Measurements were conducted for each test group by calculating the temperature rise as the difference between the start and highest temperature reading.
Results: The type of the silicone matrix used and the use of desensitizer did not affect the intrapulpal heat generation during direct provisionalization.
Conclusion: Application of a desensitizer and different type of matrix seems to be noneffective on intrapulpal heat rise, although the type of provisional material used may be effective.

The fabrication of provisional crowns or fixed partial dentures is an essential and key step in successful prosthetic treatment. Direct and indirect methods are used for the fabrication of these restorations. Due to its accuracy and pulpal protection, the indirect method is preferred over the direct method; however, time limitation and inadequate laboratory support may force the clinician to use the direct technique.[1] The most important disadvantage of the direct technique is the generation of heat during polymerization of the provisional material in the mouth.

It has been reported that a temperature rise of 5.6 °C can lead to a 15% loss of vitality in the pulp, and an 11 °C temperature rise will lead to a vitality loss of approximately 60%. In addition, a 16.6 °C temperature rise may cause 100% necrosis of the pulp.[2] Driscoll et al[3] found that the temperature increase produced by the materials ranged from 14.8 to 27.3 °C during the exothermic polymerization process of provisional materials. This finding reveals that there is a potential risk for thermal injuries when the direct technique is used. Moulding and Loney[4] reported that the use of cooling techniques, for example, air spray or the removal of the provisional crown from the tooth on initial polymerization of the resin, is effective in limiting the temperature rise in the pulpal chamber.

The effects of different types of matrices in reducing the heat transferred to the pulp by different provisional materials with the direct technique were studied by Moulding and Teplitsky,[5] who concluded that the intrapulpal temperature rise ranged from 5.42 to 7.21 °C depending on the type of the matrix used.

The use of a thin layer of resin-based dentin desensitizing agent may block dentinal tubules, which will subsequently reduce the thermal effects of external agents on the dentin sensitivity and the pulp.[6] Pashley et al[7] demonstrated that the sealing of dentinal tubules with polymeric resins reduces sensitivity and possibly the ingress of bacteria. In addition, cement base or dentin desensitizers were used in several studies as a physical barrier to achieve thermal insulation.[8,9] Although Usumez et al[8] demonstrated that no significant reduction of heat transmission was obtained regardless of the matrix type used for direct provisionalization when desensitizer was used, it is possible

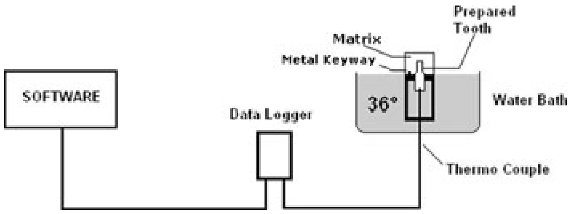

Figure 1 Test process.

that the concomitant use of dentin desensitizers as a physical barrier with different types of matrices might be effective in thermal insulation for reducing the temperature increase in the pulp chamber.

The purpose of this study was to investigate the effects of the application of a desensitizer with various matrices on the pulpal temperature increase during fabrication of different provisional restorative materials.

Materials and methods

One freshly extracted human maxillary second premolar was used for the study. The apical third of the root was resected, and the pulpal tissue was removed. A silicon-based thermal compound (ILC P/N 213414, Wakefield Engineering, Wakefield, MA) was injected into the pulp chamber. A J-type thermocouple was then inserted into the pulp chamber in the most coronal position. A radiograph was taken to ensure that the thermocouple was in contact with the overlying dentin. To prevent the movement of the probe, the apex of the tooth was sealed with an auto-polymerizing acrylic resin. Then, the tooth with thermocouple was embedded in an acrylic resin with its cervical line 1 mm higher than the base; this apparatus was used to enable the simulation of the direct provisionalization technique. One metal reference point was placed on the acrylic resin as a keyway for the standardization of the placement of matrices.

Two types of matrices were tested: addition silicone impression material (Panasil Putty, Kettenbach GmbH & Co. KG, Eschenburg, Germany) and condensation silicone impression material (Speedex Putty, Coltène AG, 9450 Altstätten, Switzerland). The materials were mixed according to the manufacturers' instructions and placed inside a plastic mold to serve as the impression tray. Impressions were made with both materials before the tooth preparation was performed. Another silicone index was fabricated and cut longitudinally for ideal tooth reduction vertically and axially. The tooth was then prepared for a metal–ceramic complete crown with a 1.5-mm shoulder finish line using a high-speed handpiece and diamond burs. The silicone index was used to control the final adequate reduction of the prepared tooth.

The test apparatus was placed in a temperature-controlled water bath at constant temperature of 36 °C (Fig 1). The water bath resulted in a baseline temperature in the pulpal chamber of approximately 30 °C.

The tested provisional materials are listed in Table 1. The provisional resins were measured and mixed according to the manufacturers' recommendations. The resin was injected into the impression matrix, which was then placed onto the prepared tooth by using the metal keyway. Each provisional resin was used in combination with each matrix. Ten restorations were made for each combination, and a total of 96 restorations were fabricated. During polymerization of the resins, the pulpal temperature changes were recorded by the inserted thermocouple. A resin-based dentin desensitizer (VivaSens, Ivoclar Vivadent, Schaan, Liechtenstein) was then coated on the prepared tooth, and 96 provisional crowns were made in the same manner on the desensitizer-coated prepared tooth. After the removal of each restoration, the tooth was cleaned with a solvent (Copalite Solvent/Thinner, Cooley & Cooley Ltd., Houston, TX), and the desensitizer application was repeated. The temperature change after the use of desensitizer was also recorded.

The thermocouple was connected to a data logger (XR440-M Pocket Logger, Pace Scientific, Inc., Mooresville, NC). The collected data were monitored real-time and were transferred to a computer. Temperature changes were recorded every 2 seconds (Figs 2–5). The end of polymerization was verified by means of the data, which were taken from graphics. When the temperature reached the water temperature, the matrix and the polymerized resin were removed from the tooth, and at least 2 minutes elapsed before another trial began. Measurements were conducted for each test group by calculating the temperature rise as the difference between the start and the highest temperature reading.

At the end of the study, the tooth was sectioned, and the remaining dentin thickness was determined. The dentin thickness was 1.3 mm buccally, 1.7 mm lingually, and 2 mm occlusally (Fig 6).

Statistical analyses

Data were expressed as mean ± standard deviation. Independent samples *t*-test and 1-way ANOVA tests were used to compare continuous variables between groups. To evaluate the interactions among the independent variables related to intrapulpal heat rise, multivariate analysis (general linear model) was used. Statistical analyses were performed with SPSS software version 14.0 (SPSS Inc., Chicago, IL).

Table 1 Provisional restorative materials tested

Product name	Manufacturer	Resin type	Lot number
Dentalon Plus	Heraeus Kulzer, GmbH, Hanau, Germany	Polyethylmethacrylate	288
Systemp C&B	Ivoclar Vivadent, Schaan, Liechtenstein	Bis-acryl	F65617
Integrity	Dentsply Caulk, Milford, DE	Bis-acryl	040129
Protemp II	3M ESPE, Seefeld, Germany	Bis-acryl	143352

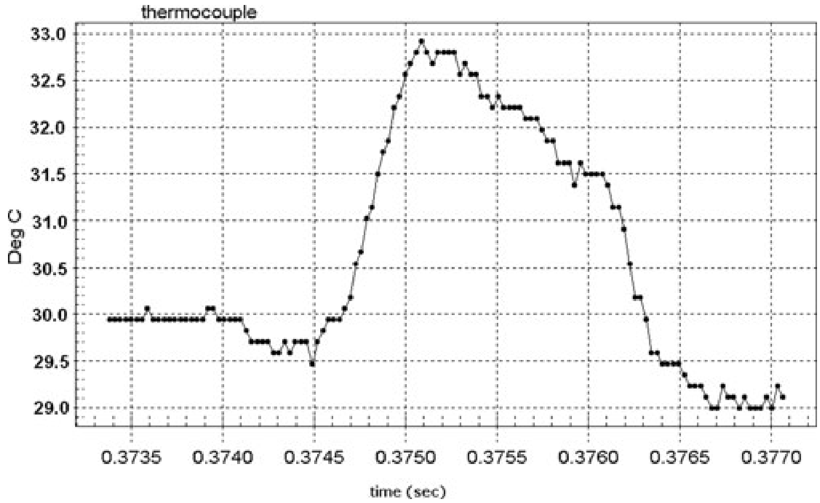

Figure 2 Temperature changes of a Dentalon Plus specimen.

Results

The mean values of the maximum temperature rise in the pulp chamber for four provisional materials according to matrix type and use of desensitizer during fabrication of the provisional crowns are shown in Table 2.

According to univariate analyses, the provisional material type used significantly affected the intrapulpal heat rise values ($p < 0.05$) while the effect of matrix type and desensitizer were insignificant ($p > 0.05$). Mean values of the maximum temperature rises were significantly different among the provisional materials ($p < 0.05$). Dentalon Plus and Integrity provisional materials produced significantly lower intrapulpal heat rise values than did Protemp II and Systemp C&B ($p < 0.05$).

According to multivariate analysis, no interactions were observed among the provisional material type, matrix type, and the use of desensitizer ($p > 0.05$).

Discussion

The effects of desensitizer application as a physical barrier and the use of different types of matrices on the intrapulpal heat rise during the fabrication of provisional crowns by direct technique were investigated in this in vitro study.

The simplicity and the shorter fabrication period make the direct technique preferable; however, the polymerization of provisional resins is an exothermic reaction, and the heat generated by the use of this technique may harm the surrounding tissues and the pulp, which should subsequently alert the clinician to protect the oral tissues from detrimental heat. Although previous studies have revealed that the threshold for the histopathological reactions occurring in the pulp during polymerization is 5.6 °C, the actual threshold of harmful temperature rise and its effects on the pulpal cells remain to be determined by well-designed histologic in vitro studies which will guide further in vivo studies and clinical applications.[2]

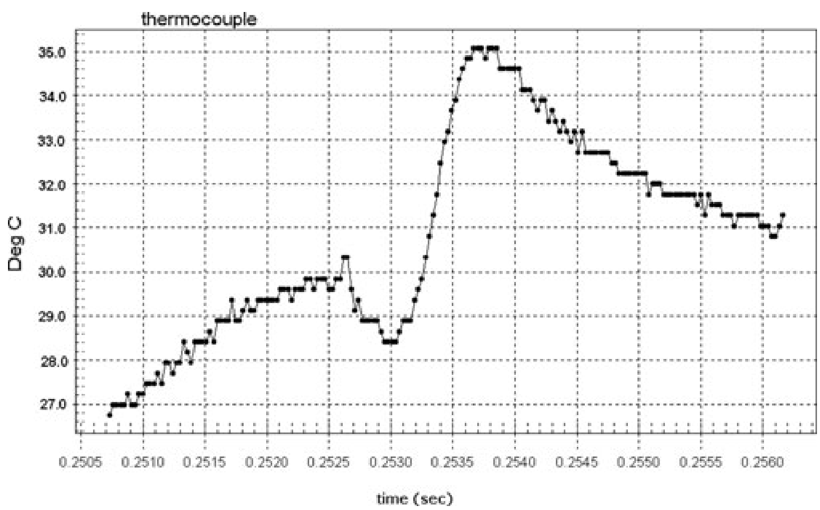

Figure 3 Temperature changes of a Systemp C&B specimen.

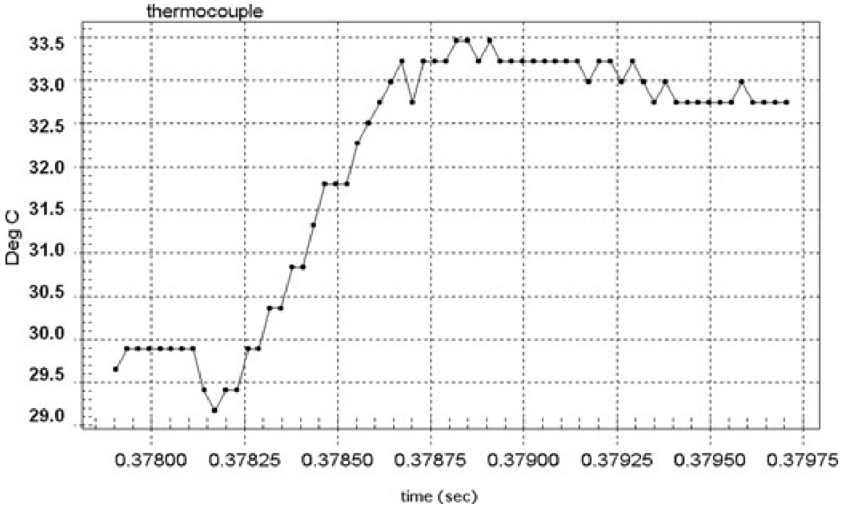

Figure 4 Temperature changes of an Integrity specimen.

Due to the poor thermal conductivity of the dentinal tissue, the thickness and the area of the residual dentin after preparation are crucial factors in the transfer of heat to the pulp.[10] The relation of the residual dentin structure and the heat flow through the dentin may be represented by a modified equation from thermodynamics:[10,11]

$$H = [KA(t_2 - t_1)]/D,$$

where H is the quantity of heat flowing through the dentin per unit time, K is the thermal conductivity of the dentin, A is the surface area of the dentin exposed to provisional resin, D is the thickness of the residual dentin, and $(t_2 - t_1)$ is the temperature difference. This equation indicates that the flow of heat through the dentin is inversely proportional to the thickness of the residual dentin. The same maxillary second premolar was used throughout this study to standardize the thickness and the area of the residual dentin and the thermal conductivity. If several teeth instead of a single one were used in this study, it would be difficult to evaluate other parameters such as matrix type and dentin desensitizer as a physical barrier, due to the difficulties in enabling the same preparation and the same dentin thickness in every tooth, which would subsequently result in different data for each specimen as can be seen from the above-mentioned formula.

The amount of heat produced by the exothermic reaction of provisional resins appears to be dependent on the amount of the material used. A larger amount of material obviously generates more heat and a proportionally higher temperature increase to the tooth during polymerization.[10,12] Therefore, in our study, to standardize the matrix placement and the amount of provisional resin polymerizing around the prepared tooth, a metal reference point was placed on the acrylic resin, which enabled the analysis of the same amount of material's effect on the temperature rise.

Application of a dentin-desensitizing agent after preparation or before cementation has been shown to be an effective mode of treatment for reducing sensitivity and other complications.[6,13-16] The dentin desensitizers obstruct the exposed

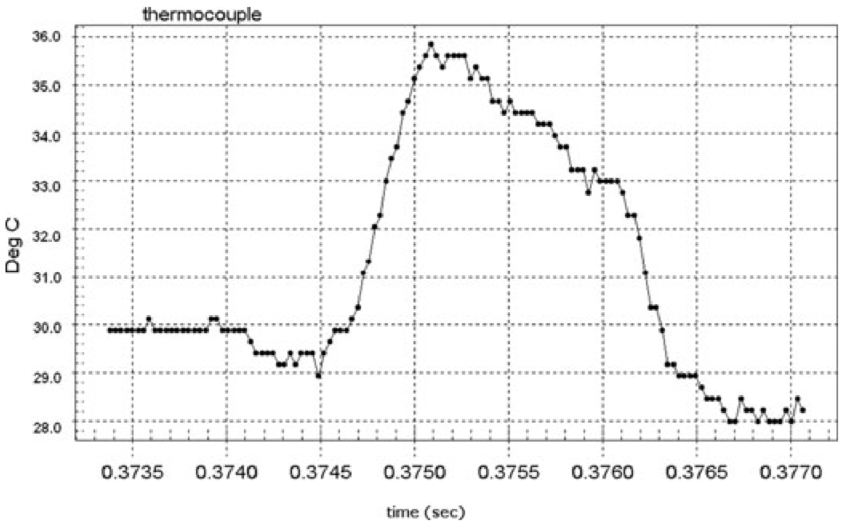

Figure 5 Temperature changes of a Protemp II specimen.

Figure 6 The sectioned tooth and thermocouple tip.

dentin tubules with a resinous material by avoiding the tubule fluid flow and reducing the ingress of bacteria and sensation of pain.[8,16] Voth et al have demonstrated that cement bases can also be used as a barrier for providing thermal insulation and the effectiveness of this barrier depends on its thickness.[9] In our study, we evaluated dentin desensitizer as a physical barrier in a thin film layer to have an effective thermal insulation; however, the results of our study revealed that the use of dentin desensitizer as a physical barrier had no significant effect on the intrapulpal heat rise during the fabrication of provisional crowns. This finding is consistent with Usumez et al's study,[8] which did not show any significant difference between temperature rise caused by the provisional materials with or without desensitizer application. They also stated that by the use of dentin desensitizing agents, the temperature rise was delayed in chemically cured groups. We did not observe this kind of finding in our study.

Although the use of a solvent to remove the film layer of dentin desensitizer may be a drawback to our study, the subsequent use of dentin desensitizer as a physical barrier without removing the previous application could result in a different thickness of this barrier, and this could cause false results. We did not investigate the interaction between the film layer and the solvent in subsequent applications, and this issue should be analyzed in detail in further studies.

One method of reducing the temperature rise during polymerization is the use of a matrix material that can dissipate the heat rapidly. Tjan et al[10] and Grajower et al[17] reported that silicone putty matrix, either the addition or condensation type, may reduce the temperature rise in the pulp chamber when compared to the phenolic resin as the matrix material. In addition, they found no difference between the types of silicone for heat dissipation. In our study, we evaluated the silicone material of both types with or without desensitizer. In agreement with other studies, we did not find any difference between each silicone as a matrix material.

The measured temperatures in this study were generally lower than the previous studies in the literature.[3,12,18] This can be explained by the differences in the test conditions. The heat rise generated during direct provisionalization is dependent on the ambient temperature[19] and the amount of the resin used.[5] In our study, the test apparatus was kept at 36 °C constantly before and during polymerization, which resulted in a 30 °C intrapulpal temperature, and a second premolar was used with a standardized method that ensured the use of the same amount of resin each time. Different ambient temperatures and material volumes were used in previous studies. In Driscoll et al's study,[3] the tooth used was a molar and the tests were carried out at room temperature. While Vallitu[18] used 750 to 3000 mm^3 volumes of the specimens at ambient temperatures of 22 °C and 37 °C; Kim and Watts[12] analyzed 115.4 mm^3 volumes of specimens at 23 °C. Therefore, direct comparative evaluation of our results with previous findings is difficult.

Zach and Cohen[2] established a safety limit of 6.1 °C to prevent pulpal damage in their study. In our study, Protemp II and Systemp C&B reached this critical limit. Also, it must be kept in mind that even though the thermocouple records no significant temperature rise, damage to vital cells can occur.[20] Therefore, some preventive methods such as cooling techniques using an air–water spray to dissipate the polymerization heat as well as to minimize the thermal trauma to the pulp, or the removal of the provisional restorations after initial polymerization, which allows the final polymerization to occur outside the mouth, may be used.[4,17,21]

Table 2 Mean values (±SD) of maximum temperature rise (°C) in the pulp chamber

	Additional silicone		Condensation silicone	
Provisional material	No desensitizer	Desensitizer	No desensitizer	Desensitizer
Dentalon Plus*,†	4.20 ± 1.52	3.50 ± 0.09	3.71 ± 0.59	3.60 ± 0.24
SystempC&B‡,§	5.60 ± 0.61	6.08 ± 0.52	5.95 ± 0.31	5.82 ± 0.19
Integrity*,†	3.72 ± 0.31	4.02 ± 0.59	3.68 ± 0.29	3.82 ± 0.24
Protemp II	5.83 ± 0.48	6.00 ± 0.30	6.20 ± 0.41	5.86 ± 0.21

*Significant difference with respect to Systemp C&B.
†Significant difference with respect to Protemp II.
‡Significant difference with respect to Integrity.
§Significant difference with respect to Dentalon.

Conclusion

According to the results of our study, Dentalon and Integrity appeared to be the least heat-producing provisional materials.

The results of this study show that the type of the silicone matrix used and application of desensitizer as a physical barrier are not effective on heat generation, which occurs during the fabrication of provisional crowns by direct technique.

Acknowledgments

This study was conducted at the Biomechanics and Materials Test Laboratory, Division of Dental Research, Faculty of Dentistry, Cukurova University. The authors thank Dr. M. Cenk Haytac for his valuable assistance.

References

1. Young HM, Smith CT, Morton D: Comparative in vitro evaluation of two provisional restorative materials. J Prosthet Dent 2001;85:129-132
2. Zach L, Cohen G: Pulp response to externally applied heat. Oral Surg Oral Med Oral Pathol 1965;19:515-530
3. Driscoll CF, Woolsey G, Ferguson WM: Comparison of exothermic release during polymerization of four materials used to fabricate interim restorations. J Prosthet Dent 1991;65:504-506
4. Moulding MB, Loney RW: The effect of cooling techniques on intrapulpal temperature during direct fabrication of provisional restorations. Int J Prosthodont 1991;4:332-336
5. Moulding MB, Teplitsky PE: Intrapulpal temperature during direct fabrication of provisional restorations. Int J Prosthodont 1990;3:299-304
6. Yim NH, Rueggeberg FA, Caughman WF, et al: Effect of dentin desensitizers and cementing agents on retention of full crowns using standardized crown preparations. J Prosthet Dent 2000;83:459-465
7. Pashley EL, Cormer RW, Simpson MD, et al: Dentin permeability: sealing the dentin crown preparations. Oper Dent 1992;17:13-20
8. Usumez A, Ozturk AN, Aykent: The effect of dentin desensitizers on thermal changes in the pulp chamber during fabrication of provisional restorations. J Oral Rehabil 2004;31:579-584
9. Voth ED, Phillips RW, Swartz ML: Thermal diffusion through amalgam and various liners. J Dent Res 1966;45:1184-1190
10. Tjan AH, Grant BE, Godfrey MF: Temperature rise in the pulp chamber during fabrication of provisional crowns. J Prosthet Dent 1989;62:622-626
11. Mucci JF, Stearns RL: The Fundementals of Physics and Chemistry (ed 1). Columbus, OH, CE Merrill, 1968, pp. 385-403
12. Kim SH, Watts DC: Exotherm behavior of the polymer-based provisional crown and fixed partial denture materials. Dent Mater 2004;20:383-387
13. Felton DA, Bergenholtz G, Kanoy BE: Evaluation of the desensitizing effect of Gluma Dentin Bond on teeth prepared for complete-coverage restorations. Int J Prosthodont 1991;4:292-298
14. Watanabe T, Sano M, Itoh K, et al: The effects of primers on the sensitivity of dentin. Dent Mater 1991;7:148-150
15. Trowbridge HO, Silver DR: A review of current approaches to in-office management of tooth hypersensitivity. Dent Clin North Am 1990;34:561-581
16. Brannstrom M: Communication between the oral cavity and the dental pulp associated with restorative treatment. Oper Dent 1984;9:57-68
17. Grajower R, Shaharbani S, Kaufman E: Temperature rise in pulp chamber during fabrication of temporary self-curing resin crowns. J Prosthet Dent 1979;41:535-540
18. Vallittu PK: Peak temperatures of some prosthetic acrylates on polymerization. J Oral Rehabil 1996;23:7767-7781
19. Wolcott RB, Paffenbarger GC, Schoonover IC: Direct resinous filling materials: temperature rise during polymerization. J Am Dent Assoc 1951;42:253-263
20. Seltzer S, Bender IB: The Dental Pulp (ed 2). Philadelphia, PA, Lippincott, 1975, p. 203
21. Lui JL, Setcos JC, Phillips RW: Temporary restorations: a review. Oper Dent 1986;11:103-110