Clinically Relevant Issues Related to Preheating Composites

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ABSTRACT

Statement of the Problem: Issues regarding the use of composite preheating need to be investigated so that the clinician will better understand the variables associated with this method.

Purpose: To examine the multiple aspects of use of a commercial composite preheating device (Calset, AdDent Inc., Danbury, CT, USA).

Materials and Methods: Temperature values of three heating units and composite compules were obtained using a K-type thermocouple and were recorded digitally in real time. The following parameters were measured: maximum heater and composite temperature and its stability upon storage, composite temperature change when removed from the heater and injected, the effect of delivery system on ejected composite temperature, and the effect of repeated and extended preheating on composite monomer conversion (using infrared spectroscopy). Monomer conversion was measured after repeated composite cycling (from room temperature [RT] to 60°C, 10×) or extended preheating (24 hours at 60°C), and values were compared with composite maintained at RT (control group). Among test parameters, data ($N = 5$ for each parameter) were analyzed using Student's *t*-test, analysis of variance, and the Tukey–Kramer post-hoc test where appropriate (alpha = 0.05).

Results/Conclusions: Two of the three tested units achieved the stated preset temperatures. Composite attained temperature values close to the heating unit. Composite temperature drop upon removal from the heater was dramatic: within 2 minutes a 50% temperature drop was noted. Heating the compule while preloaded in the syringe provided higher delivery temperatures than heating the compule separately ($p < 0.00$). Optimum results were achieved when preheated composite was dispensed and used as quickly as possible. Neither repeated nor extended preheating of composite significantly affected monomer conversion.

CLINICAL SIGNIFICANCE

Preheating composite has potential benefits, but should be used with knowledge of its limitations. Reheating of unused composite does not affect its degree of conversion, thus decreasing material waste. Heating of the composite preloaded in the delivery syringe enhances the temperature of extruded composite.

(*J Esthet Restor Dent* 18:340–351, 2006)

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DOI 10.1111/j.1708-8240.2006.00046.x

INTRODUCTION

Current methods for placing composite into cavity preparations have many problems. The high viscosity and stickiness of highly filled composite makes insertion, as well as adaptation, of the material to preparation walls difficult and unpredictable.[1,2] Also, the extent of resin polymerization under room temperature (RT) conditions yields polymers of relatively low monomer conversion.[3]

A recently marketed commercial device (Calset, AdDent Inc., Danbury, CT, USA) claims to preheat composite compules to 54, 60, or 68°C and stores them at the preset temperature until ready for use.[4] A small number of compules can be preheated and left at the preset temperature prior to placement in a delivery syringe and injection into the preparation. An attachment is also available so that a compule-loaded syringe is preheated, saving clinical delivery time, and perhaps minimizing compule cooling upon transfer to the tooth (Figure 1).

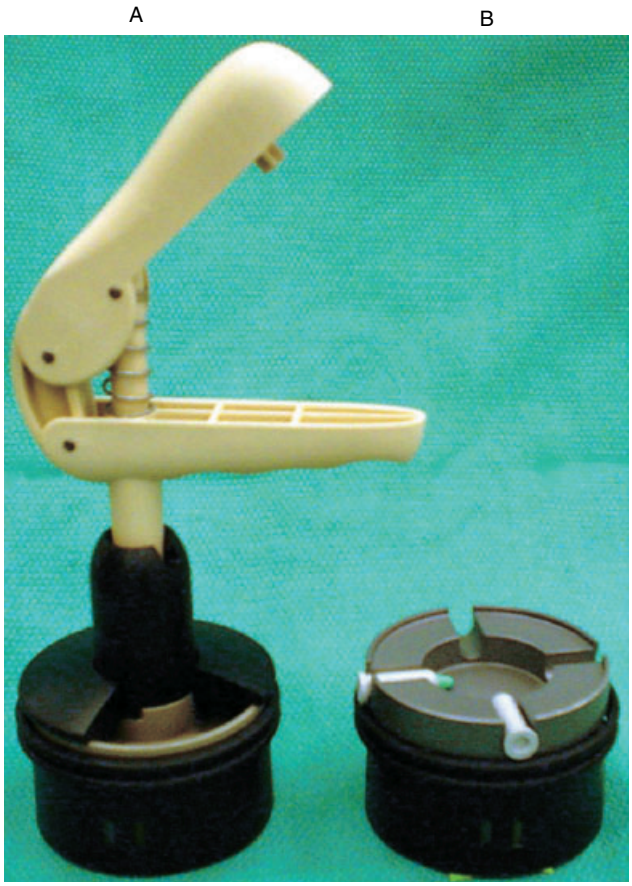

Figure 1. Calset unit and respective trays. A, Dispenser gun tray. B, Standard compule tray with lid removed to show compule placement.

The effect of preheating resin systems has many potential benefits. Flow of commercial hybrid composites can greatly increase upon preheating.[5] However, the extent of flow varies among brands and composite classifications. The heated composites tested initially are a higher viscosity material, the flowability of heated material never reaches the low levels of an RT, flowable composite.[5] The overall extent and rate of monomer conversion in model, unfilled resin systems cured at higher temperatures are enhanced over that performed at RT.[3,6–9] Recent studies using a commercial resin composite indicate a significant increase in conversion upon preheating, as well as an increase in cure rate and conversion attained at maximum cure rate.[3,10,11] As with any new device marketed for enhancing a clinical technique, the performance and claims of the unit need to be verified so that the clinician can rely on consistent product performance and possible enhancement over procedures currently being used.

The thermal properties of the Calset unit as well as of preheated composites are largely unknown.

The unit and composite temperature rise and the heating rates are also unknown. Quite often, clinicians store composite in a refrigerator to prolong product shelf life or to use it in a cold, more viscous state for possible enhancement of proximal contact as well as ease in carving anatomy.[12] However, the time for refrigerated material to reach RT and then to reach elevated temperature once placed into the Calset is not known. It is also not known if the type and size of the compule itself has an influence on the temperature rise of composite. Furthermore, consistency in performance among individual heating units is essential to know to determine if the preset temperature values are reached in the composite itself, and how well composite temperature is controlled upon compule storage. Decrease in composite temperature upon removal from the heating device and the time required to transfer and deliver that material to a tooth preparation needs to be measured. The effect of repeated preheating and cooling as well as extended periods of compule preheating on composite cure are valid concerns, as extended heating may lead to inferior performance of compule contents warmed, but not used.

The purpose of this article is to examine the influence of the previously mentioned concerns in a laboratory situation. Time to attain a predetermined temperature, maximum composite temperature attained, temperature change, cycling time, and temperature oscillation were assessed using the Calset set at both of its presettable temperatures: 54 and 60°C. The temperature change of composite stored in a refrigerator to reach RT and temperature loss upon composite transfer from the heating unit and injection into a simulated preparation were measured. The effect of repeated heating and cooling, as well as extended heating on monomer conversion of composite was measured and compared with that of unheated, RT material (control).

MATERIAL AND METHODS

Temperature Measurement

K-type thermocouples (part # TT-K-30-SLE, Omega Engineering Inc., Stamford, CT, USA) were fabricated by joining wire ends with a spot welder (Model R660, Rocky Mountain/Orthodontics, Denver, CO, USA). Each thermocouple was joined to an electronic cold junction compensator (Omega Engineering Inc., Stamford, CT, USA). The output from the compensator was directed to a 16-bit analog-to-digital converter (SMAD II, MorganKennedy Research, Cambridge, MA, USA) and recorded in real time, at a data acquisition rate of 10 data points per second using a software (SMADCHROM v 2.02, MorganKennedy Research). Using standard K-type thermocouple conversion tables (Omega, 1991), the recorded millivoltage data were converted into temperature values.

Time to Maximum Temperature (Tmax) and Tmax Attained by the Calset

Three Calset units were used: Sn #080451, Sn #081083, and Sn #081084. A small hole was drilled into the well of the removable heater tray and a thermocouple was fixed to the tray using cyanoacrylate adhesive. The tray temperature was recorded for 2 minutes, representing the value of the RT baseline. The heating unit was then turned on and the temperature values were recorded for 30 minutes. Five replications for each test condition were made. The time required to reach Tmax, the Tmax attained, and the temperature change between baseline and Tmax were calculated at both the selectable 54 and 60°C preset temperature settings. The effect of preset temperature on time to reach Tmax was analyzed using Student's *t*-test. One-way analyses of variance (ANOVAs) were performed to detect differences in Tmax values reached and time to maximal temperatures among Calset units at each preset temperature. For this analysis and all subsequent analyses, the level of statistical significance used is a preset alpha of 0.05.

Calset Temperature Cycling
The temperature stability of the Calset at the preset value was assessed by placing a K-type thermocouple on the Calset flat plate, between the heater and tray. The unit (Sn #080451) was tested at both preset temperatures (54 or 60°C). Millivoltage output was recorded for 10 minutes. Maximum and minimum temperatures, temperature change, and cycling time were determined. Statistical comparison of temperature change and cycling time between preset temperatures was made using one-tailed Student's *t*-tests.

Effect of Compule/Composite Type on Temperature Values
Two different composite compule types were used: Esthet•X (shade C2, lot #0006233, Dentsply/Caulk, Milford, DE, USA) and Herculite XRV (shade C2, lot #910968, Kerr Corp., Orange, CA, USA). A K-type thermocouple was inserted into the composite mass from the compule distal end. If a plunger was removed to gain access, it was replaced (Herculite). When a hole was drilled in the plunger to insert the wires (Esthet•X), it was sealed with cyanoacrylate cement. Radiographs were taken to confirm thermocouple placement within the center of the composite mass.

Temperature values of both compules were obtained for 30 seconds at RT (baseline). Both compules were simultaneously positioned in separate wells of the same heating unit (Sn #080451) and maintained in place for 15 minutes with the unit lid on. Composites were tested at both of the unit's preset temperatures. After 15 minutes, the compules were removed and allowed to cool to RT. Data were recorded for 30 additional minutes during this phase. Baseline (RT), Tmax, temperature change on heating, time to attain Tmax, and time to return to baseline temperature were measured. Two-tailed, unpaired Student's *t*-tests were performed to access the effect of compule type within a preset temperature and the effect of preset temperature for a specific composite. The time/temperature profiles for one compule type (Esthet•X) were also recorded when the refrigerator-stored specimen (3°C) was allowed to warm to RT. Five replications were made for each test parameter.

Effect of Delivery System
A single composite compule for preheating can be either loaded into a composite delivery syringe and placed together into the Calset, or the compule can be heated separately, removed, and then placed individually into the syringe. The expressed composite temperature and the time differences in delivery methods were examined by simulating composite placement into a 2-mm-deep preparation. The facial enamel of a bovine incisor was ground flat with SiC paper. An access hole was drilled from the lingual surface through to the buccal surface. A K-type thermocouple was threaded through the lingual access and then sealed and stabilized using acid etching and a flowable composite (Filtek Flow, lot #20030107, 3M-ESPE, St. Paul, MN, USA). The thermocouple junction was positioned just above the flat tooth surface. A brass ring (6-mm diameter, 2-mm height) was placed on the facial tooth surface with the thermocouple in the center and secured with cyanoacrylate cement, simulating the tooth preparation. Two Calset units (Sn #080451 and #081083) were preset to 60°C. Compules were preheated either individually in the heating unit storage well or were preloaded in a delivery syringe, which was then placed in the heater using the supplied attachment. After 15 minutes of preheating, each compule type was removed from the Calset, and its contents expressed into the brass ring and then contoured flat while the temperature at the tooth surface was continuously recorded. The elapsed time between removal of the composite compule from the Calset unit and the beginning of placement as well as the composite temperature change during this phase were recorded for both delivery methods. Five replications for each test condition were made. Multiple one-tailed Student's *t*-tests were performed for each event to

detect differences between the two delivery methods.

Effect of Repeated and Extended Composite Preheating on Monomer Conversion

Three commercially available photoactivated resin composite materials that represented a range in filler loading and classification were selected (Table 1).

The Calset unit was set to 60°C. Compules ($N = 5$) were submitted to one of the following temperatures cycles: control—composite at RT (no preheating); repeated preheating (reheating)—10 continuous cycles of preheating and cooling. With the Calset ready to use, a single cycle consisted of leaving compules in the prewarmed Calset for 15 minutes (from RT to 60°C), removing them, and allowing them to cool for an additional 15 minutes (from 60°C back to RT); and extended preheating—compules were left in the Calset and preheated continuously for 24 hours (from RT to 60°C) and then cooled to RT.

Twenty-four hours after the different temperature treatments, the uncured composite compule contents (now all at RT) were placed on an attenuated-total-reflectance (ATR) unit (MKII Golden Gate, SPECAC, Smyrna, GA, USA) of a Fourier transform infrared spectrometer (FTS-40, Digilab/Bio-Rad, Cambridge, MA, USA), covered with a Mylar sheet, pressed into a thin, flat disk (approximately 150 µm), and photopolymerized for 20 seconds using a conventional quartz-tungsten-halogen curing unit (Optilux 501, Demetron/Kerr Co., Orange, CA, USA) with the distal tip end secured 1 mm from the Mylar surface. Spectral irradiance of the light source was determined using a laboratory-grade spectral radiometer (DAS 2100, Labsphere, North Sutton, NH, USA) having a 3-inch integrating sphere and calibrated using a National Institute of Standards and Technology–traceable source. The power density of the light source measured 630 mW/cm^2 between 350 and 600 nm.

The temperature of the ATR stage was controlled at 35°C to simulate intraoral temperature by use of its self-contained, computer-controlled heater (3000 Series High Stability Temperature Controller, SPECAC, Smyrna, GA, USA). Infrared spectra were obtained using 16 scans at a resolution of 2 cm^{-1} 5 minutes after light initiation. Five replications for each test condition were made. Monomer conversion was calculated from infrared spectra using standard methods. These methods utilize changes in the ratios of aliphatic-to-aromatic C = C absorption peaks in the uncured and cured states that were correlated to values obtained using a series of known calibration solutions.[13–15] Conversion values were compared using ANOVA and the Tukey–Kramer post-hoc test.

RESULTS AND DISCUSSION

Time to Tmax and Tmax of the Calset are shown in Table 2 and Figure 2. Tmax attained was 53.7 ± 0.8°C (Sn #081083, with Calset preset to 54°C) and 59.3 ± 0.6°C (Sn #081084, with Calset preset to 60°C). A significant difference in maximum attained temperature

TABLE 1. COMPOSITE MATERIALS USED.

Classification	Brand	Shade	Lot	Manufacturer	Location
Conventional submicron hybrid	Esthet•X	A2E	0302054	Dentsply Caulk	Milford, DE, USA
Nanofilled hybrid	Filtek Supreme	A2B	2AA	3M-ESPE	St. Paul, MN, USA
Packable	Prodigy Condensable	A2	403878	Kerr	Orange, CA, USA

TABLE 2. TIME TO TMAX, TMAX ATTAINED, AND TEMPERATURE CHANGE FROM RT OF CALSET UNITS PRESET TO 54°C OR 60°C (MEAN [SD]).

Preset Temperature	Time to Tmax (minutes)	Tmax Attained (°C)	Temperature Change from RT Baseline (°C)
54°C			
Sn #080451	10.7 (0.5)$_a$	49.2 (0.4)$_a$	28.3 (0.5)
Sn #081083	10.1 (0.6)$_a$	53.7 (0.8)$_b$	32.2 (0.2)
Sn #081084	11.7 (1.5)$_a$	53.6 (0.3)$_b$	31.9 (0.3)
60°C			
Sn #080451	10.7 (0.9)$_a$	55.1 (1.0)$_a$	34.0 (0.8)
Sn #081083	11.3 (0.4)$_a$	58.7 (0.5)$_b$	36.9 (0.8)
Sn #081084	10.7 (0.9)$_a$	59.3 (0.6)$_b$	37.7 (0.7)

RT = room temperature; Tmax = maximum temperature.
For each preset temperature within a column, unit groups having similar lower case letters are not significantly different ($p > 0.05$). $N = 5$ replications per unit.

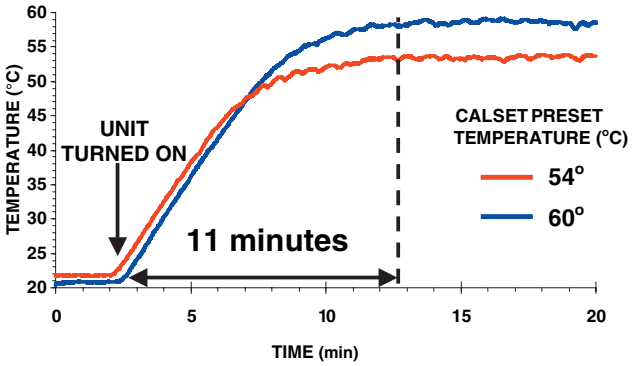

Figure 2. Example of real-time temperature plot of the Calset unit itself when heating from room temperature to each of the two preselected temperatures. N = 5 specimens per experimental condition.

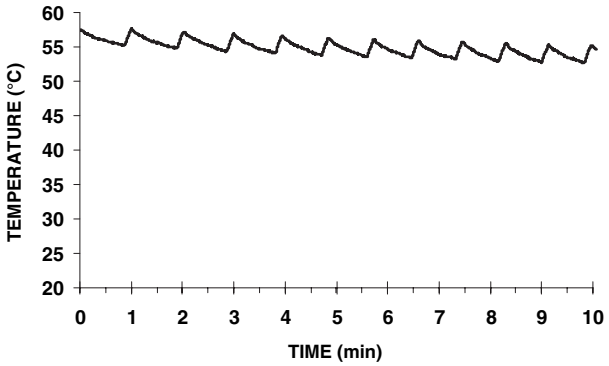

Figure 3. Close up of Calset cycling profile at maximum temperature (preset to 60°C). N = 5 specimens per experimental condition.

was found among the three units tested for both 54 and 60°C preset temperatures. Temperature variation was seen to be influenced by the lower readings obtained with an individual unit: Sn #080451. No statistical difference was observed when comparing both preset temperatures regarding the heating time ($p = 0.3865$), ie, it took the same time for the device to warm to either of the two preselected temperatures (54 or 60°C). In both cases, 11 minutes of warming were sufficient to reach the maximum unit temperature.

Following attainment of Tmax, the heating device cycles, and temperature oscillates with time (Figure 3). During cycling, temperature change was 7.3 ± 2.3°C with the device preset to 54°C (from a low of 41.9 ± 0.9°C to a high of 49.2 ± 1.9°C), and 4.4 ± 1.0°C with the device preset to 60°C (from a low of 52.9 ± 1.6°C to a high of 57.3 ± 2.1°C). Cycling time was 0.88 ± 0.08 minutes (preset to 54°C) and 0.94 ± 0.09 minutes (preset to 60°C). Statistical comparison of temperature change between preset temperatures showed a significant higher change

in temperature when the Calset was preset to 54°C ($p = 0.0282$) and no statistical difference regarding cycling time ($p = 0.5816$).

Table 3 and Figure 4 show the effect of compule types on temperature values within a preset temperature and the effect of preset temperature for a specific composite. Different compule types did not affect temperature values ($p > 0.05$). Maximum compule temperature attained was 48.3 ± 0.7°C when the unit was preset to 54°C, and 54.7 ± 1.9°C when preset to 60°C. Although the compule contents' Tmax values were lower than the preset temperatures, composite did reach temperatures very near that of the heating device. The unit used for testing (Sn #080451) demonstrated the lowest temperature values (49.2°C when preset to 54°C and 55.1°C when preset to 60°C) of the three units tested. From this data, it is obvious that sufficient time was provided for the composite to reach and maintain the heating unit value. Slightly lower composite temperature compared with that of the heating source would be expected, because composite is filled with inorganic particles and organic resins that function as thermal insulators. The more filled the material, the more it will thermally behave as a glass filler. The similar heating profiles for the two composite compules tested may be due to their similar volumetric filler loading: 60% (Esthet•X) and 59% (Herculite XRV) (manufacturer-supplied information). Composites with different compositions (high filler loading = packable; low filler loading = flowable) may take different times to reach stable temperature. Thus, when utilizing the preheating technique, the clinician should be aware of these factors, as they may influence the time needed for compule/syringe contents to reach the target temperature.

Previous work demonstrated that composite preheating can result in reduced exposure times while attaining similar conversion as that of RT material, as long as

TABLE 3. COMPARISON OF CALSET PRESET TEMPERATURE WITH PREHEATED COMPOSITE COMPULE TYPE AND TEMPERATURE (MEAN [SD]).

Composite and Compule Type	Calset Preset Temperature		*p*-Value*
Esthet•X	**54°C**	**60°C**	
Baseline (°C)	21.3 (0.3)	20.9 (0.9)	0.3466
Tmax (°C)	48.3 (0.7)	54.7 (1.9)	0.0001
ΔT (°C)	26.9 (0.9)	33.8 (2.6)	0.0005
Time to Tmax (minutes)	11.6 (2.0)	12.0 (1.3)	0.7041
Time to cool to RT (minutes)	9.5 (2.5)	10.0 (1.5)	0.6944
Herculite XRV			
Baseline (°C)	21.3 (0.3)	20.9 (0.9)	0.3466
Tmax** (°C)	47.8 (0.7)	53.9 (1.6)	0.0001
ΔT*** (°C)	26.5 (0.8)	33.0 (2.3)	0.0003
Time to Tmax (minutes)	12.8 (1.9)	11.5 (2.0)	0.3479
Time to cool to RT (minutes)	10.2 (2.4)	10.4 (1.7)	0.8810

Tmax = maximum temperature; ΔT = temperature change relative to RT value; RT = room temperature.
*Related to values within the same row; *p*-values less than 0.05 indicate statistical significance. *N* = 5 specimens per experimental condition.

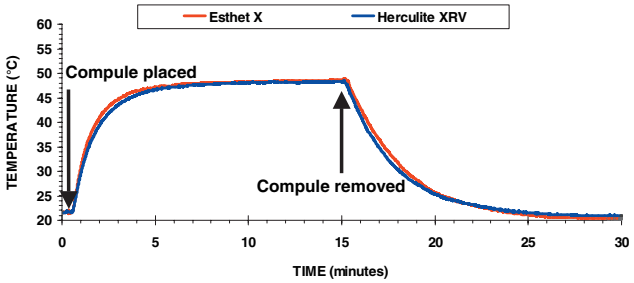

Figure 4. Temperature profile of compules placed and removed from the Calset unit preset to 54°C. N = 5 specimens per experimental condition.

composite temperature is maintained.[3,10] However, for composite warmed in the Calset, the temperature decreased rapidly after extrusion from the compule. Figure 5 shows the percentage of preheated composite temperature drop as a function of time after removal from the Calset. For this purpose, Tmax attained while within the heating unit was considered as 100%. All temperature drop profiles (Figure 5) demonstrate very good fits to logarithmic regressions. In all cases, a large temperature loss was observed in a short period: 50% of the temperature attained was lost after 2 minutes of composite removal and almost 90% after 5 minutes. These results stress that, in order to achieve best clinical performance with the Calset, the clinician must work very quickly to ensure the least temperature drop possible. The dispensed material should be placed, adapted, contoured, and light-cured in minimal time to attain potential added conversion above that of RT values. Additionally, a longer heat soak might be necessary to reduce the cooling effect when a composite compule is removed from the Calset unit.

Figure 6 presents the temperature increase profile as a function of time when a refrigerator-stored composite compule was allowed to return to RT. The average refrigerator temperature was 3.5 ± 0.1°C. From this temperature, 11 minutes were required for the compule contents to reach RT (22.8 ± 0.1°C). Thus, the clinician should wait at least this amount of time before using composite stored in a refrigerator, as monomer

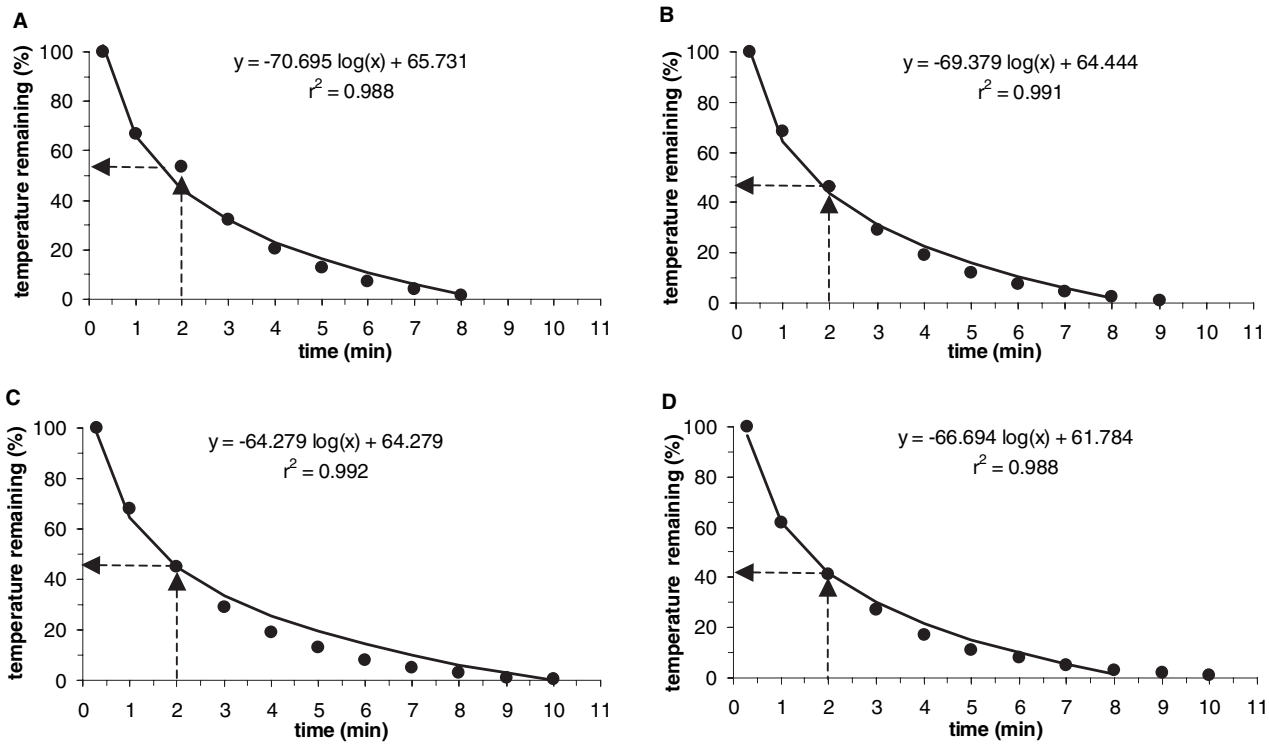

Figure 5. Composite temperature loss upon removal from the Calset unit. A, Esthet•X, 54°C. B, Herculite, 54°C. C, Esthet•X, 60°C. D, Herculite, 60°C. N = 5 specimens per experimental condition. Arrows indicate percentage of preheated composite temperature loss 2 minutes after removal from the heating unit.

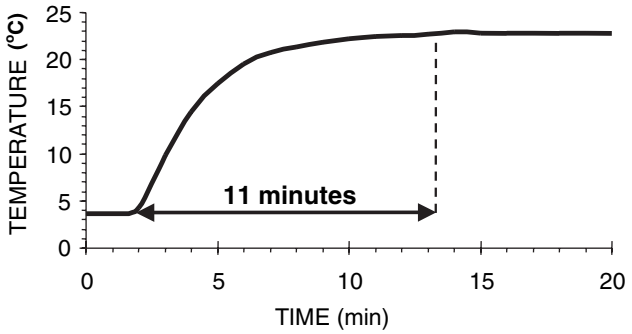

Figure 6. Typical time–temperature profile of composite within a compule stored in a refrigerator (3°C) and removed to room temperature (22.8°C). N = 5 specimens per experimental condition.

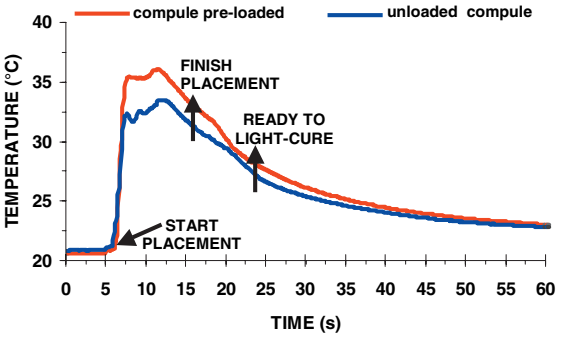

Figure 7. Effect of delivery method for preheated composite compule: temperature change as a function of time in a simulated tooth preparation from beginning of placement. N = 5 specimens per experimental condition.

conversion occurring below RT is much lower.[3]

Figure 7 shows the effect of composite delivery system on temperature values. When comparing both delivery methods, the composite compule already loaded into a delivery syringe was more efficient: higher temperatures were attained with this method as opposed to preheating the compule separately. The Tmax of composite loaded into a delivery syringe was significantly higher (36.6 ± 2.2°C) than when a compule was preheated separately (33.6 ± 0.5°C) ($p = 0.0181$). The maximum temperature change with respect to baseline values was higher ($p = 0.0091$) when the compule was heated while within the syringe (16.2 ± 2.2°C) than it was when the compule was preheated separate from the syringe (12.8 ± 0.2°C). The time elapsed from compule removal from the Calset to the beginning of placement also varied statistically between the two groups. With the preloaded compule, 6.3 ± 1.1 seconds were required, while when having to load the preheated compule 10.8 ± 1.9 seconds were required: a difference of 4.5 seconds ($p = 0.0019$). Given the fact that composite cools at a very rapid rate after removal from the preheating unit, any time saving is essential in enhancing the performance of the prewarmed material. This 4.5-second time was responsible for a 3°C difference between the two methods. Therefore, preplacement of the compule directly into the delivery syringe during compule preheating seems advantageous over the use of preheating only the individual compule itself.

TABLE 4. MONOMER CONVERSION OF ROOM TEMPERATURE AND REPEATED OR EXTENDED-HEATED COMPOSITE [MEAN (SD)].

	Room Temperature	Repeated (10×)	Extended (24 hours)
Esthet•X	53.6 (0.9)	54.0 (0.6)	53.9 (0.4)
Supreme	53.5 (0.6)	52.3 (0.8)	53.7 (0.5)
Prodigy	58.4 (0.3)	58.0 (1.5)	58.7 (0.6)

Within a row, there were no statistically significant differences among conversion values for the different heating conditions ($p > 0.05$). $N = 5$ specimens per experimental condition.

The effect of repeated and extended composite preheating on monomer conversion is presented in Table 4. Three different commercial resin composite types were tested and for all of them, neither repeated preheating and cooling nor extended preheating affected the monomer conversion of composite with

respect to the specimen group that remained at RT (control). For each composite tested, monomer conversion, either after repeated or extended preheating, remained equivalent to RT values. These results indicate that no resin polymerizable components were lost upon heating, nor was there any degradation of monomer during the different heating treatments. The clinical concern is if preheated composite is not used immediately, degradation of resin components or a premature curing of the materials would occur. Under the extreme conditions of temperature storage and cycling imposed during this testing, it can be concluded that exposure of sealed compules to such thermal insults does not degrade their ability to polymerize.

Increased polymerization temperature increases conversion of dimethacrylate monomers, but only up to a certain temperature limit. After that limit, monomer conversion decreases with subsequent temperature increase. For monomers such as Bis-GMA or BisEMA, this limit occurs near 90°C.[8,17] Decrease in monomer conversion from excessive elevated temperature occurs due to reactant evaporation and photoinitiator degradation.[11] Dimethacrylate dental monomers have limited volatility over the temperature range in which the Calset preheating technique is proposed.[11] On the other hand, some low molecular weight components of the photoinitiator system could be volatilized when resin is subject to extended heating.[18] However, this potential was found using ultraviolet-induced (and not blue light) resin systems. Previous work has shown that dimethacrylate monomers do not undergo spontaneous thermal polymerization until temperatures exceed 140°C.[11] Others observed an increase of thermal conversion in detriment to that of light-cured conversion when temperature was above 100°C.[8] Nevertheless, the temperatures used for preheating can be considered safe, as even 90°C is 30°C above the maximum preset temperature of the Calset (60°C). Because elevated temperatures may volatilize reactive components, it should be stressed that compule caps and plungers be checked for security prior to and subsequent to heating (if reused).

Preheated composite temperature drop when removed from the heating device was dramatic, and occurred during all the times of simulated operative steps in this study. It will be very important to determine composite temperature in a clinical scenario, when preheated composite is placed on prepared tooth structure. Also, the intrapulpal temperature rise using preheated composite needs to be evaluated for possible iatrogenic damage. Studies are currently underway to investigate these issues.

CONCLUSIONS

Within the limitations imposed by this study, the following conclusions may be made:

1. Two of the three tested heating devices reached the stated preset temperatures, and one did not.
2. Composite temperature inside the heated compule reached temperatures near that of the heating unit.
3. Composite temperature decreased rapidly upon compule removal from the heating device.
4. Preheating the combination of compule and syringe as opposed to a compule only provided higher composite temperatures at delivered and required less delivery time.
5. Neither prolonged, elevated preheating nor repeated compule heating affected the degree of conversion of composites preheated compared with composites maintained at RT.

DISCLOSURE AND ACKNOWLEDGMENTS

The authors greatly appreciate the talents of Mr. Don Mettenburg and his assistance in this work. This study was supported by CAPES Brazil (Grant 03/48031) and The Medical College of Georgia. The authors thank AdDent and

Dentsply/Caulk for their donation of the equipment and materials used.

This article is based on research submitted in partial fulfillment of requirements for the PhD degree of Dr. Marcia Daronch, University of São Paulo, São Paulo, SP, Brazil.

The authors have no financial interest in any of the companies whose products are included in this paper.

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