In Vivo Measurement of Root Canal Wall Temperature at Different Stages Prior to Fiber Post Cementation

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Abstract

Objective This study measured the in vivo temperature of prepared root canal walls during various stages of treatment prior to endodontic postcementation.
Materials and Methods One tooth each from five patients requiring endodontic treatment received conventional gutta-percha obturation. The coronal 4 mm of gutta-percha was removed by drilling and the canal wall temperature was measured. A sterile, saline rinse was applied, and another temperature value was recorded. Paper points were placed, and the wall temperature was recorded. A standardized period of 1.5 minute passed, simulating time needed to mix and place the resin cement and post (no resin was placed), after which the final wall temperature was obtained. The tooth was temporized and scheduled for prosthetic reconstruction. A one-way repeated measure analysis of variance (with Tukey's *post hoc* test) was performed among mean temperature values for each treatment stage (preset α 0.05).
Results Significant temperature differences were found among the treatment stages. Canal space drilling yielded the highest temperature (35.5 ± 0.8°C), while the lowest was obtained after saline rinsing (34.0 ± 0.9°C). The temperature of prepared root canal wall prior to postplacement (34.9 ± 1.2°C) and following paper point drying (34.8 ± 1.1°C) presented intermediate results, with no statistical difference between them.
Conclusions This study suggested that root canal wall temperature varied during various stages of preparation prior to endodontic post.

Keywords
► postcementation
► postspace preparation
► resin cement
► root canal wall temperature

Introduction

It is logical to assume that the tooth root temperature is near to that of the surrounding periodontium, as the root is totally embedded within this mass of tissue having an extensive blood supply. In vitro studies of intracanal temperatures when using warm gutta-percha techniques indicate that temperatures are greatly elevated, depending on the heating instrument's power setting, ranging between 8 and 65°C.[1] However, when restoring a tooth for a fiber post, the root surface is prepared using rotary instrumentation to remove dentin, enabling the post to intimately adapt to the canal space. The temperature of the internal root space as a result of this mechanical friction may also be elevated, and the resin cement may achieve an even higher temperature during curing.[2] However, when clinically restoring a root with a post, multiple clinical steps are performed, which may affect the temperature of the prepared root surface in an opposite direction, such as the influence of saline rinses and paper point drying prior to and subsequent to canal postspace drilling. Thus, it is not clear if the prepared canal wall temperature would positively enhance polymerization through elevated temperatures, or negatively impact the cure from being cooled. A literature search did not reveal any in vivo studies that measured the prepared canal wall temperatures during the sequences of postplacement.

Studies involving investigation of the curing potential, mechanical, and chemical properties of endodontic resin cements have either made, stored, and tested specimens

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at room temperature or made specimens at room temperature and then stored them at 37°C in a variety of manners and for different times, prior to testing.[3–9] As the temperature increase can influence the degree of conversion and consequently the physical properties of the restorative materials,[10,11] it is important to know the real temperature of the internal structures of the root canal to understand its consequences in the polymerization of the materials placed inside the canal. Indeed, polymerization strain values have been found to significantly increase between room temperature and 37°C.[12] In addition, increase in conversion was found to result in a two orders of magnitude increase in elastic modulus.[13] Because fiber posts are designed to have elastic moduli near that of dentin,[14] it would seem advantageous to also enhance the modulus of the cement layer to help establish a unified stress distribution in the restored tooth, although other factors such as storage time and water play significant roles.[15,16]

The purpose of this work was to measure the in vivo root canal wall temperature during various stages of preparation to receive an endodontic fiber post. Real-time temperature measurements were obtained from five separate individuals who required endodontic therapy. The teeth measured and canals entered represented a variety of anterior and posterior locations as well as maxillary and mandibular teeth. The research hypothesis was that no difference in the temperature of the root canal wall space would be found among the various stages of preparation.

Materials and Methods

Ethical Aspects

The clinical protocol for obtaining in vivo canal wall temperatures was approved by the Ethics Committee for Research, Piracicaba School of Dentistry, University of Campinas, Piracicaba, SP, Brazil (approval #100/2011). Five patients, one male and four females, with ages ranging from 19 to 56 years, were tested. ►**Table 1** shows the characterization of the treated teeth.

Root Canal Treatment

Conventional endodontic therapy was applied in all cases. Patient symptomology was accessed and pretreatment radiographs were obtained. Patient inclusion criteria required that diagnostic analysis should reveal the presence of irreversible, acute pulpitis. Local anesthesia (alphacaine 100, lidocaine 2% with 1:100,000 epinephrine, DFL, RJ, Brazil) was injected, and the tooth was isolated using a rubber dam. Endodontic access was made, and working length values were initially determined using an electronic apex locator (NovApex, Romidan LTD, Kiryat-Ono, Israel) and verified using a size #15 K-file and a radiograph. The root canals were instrumented using nickel-titanium rotary files (VDW GmbH, Munich, Germany) up to size #35. Irrigation was performed using a 5-mL disposable plastic syringe (Ultradent Products Inc., South Jordan, Utah, United States) with a polypropylene capillary tip (Ultradent) placed passively into the canal, up to 2 mm from the apical foramen without binding. During instrumentation, irrigation was performed, alternating between distilled water and 2% chlorhexidine gel (Endogel, Essencial Pharma, Itapetininga, SP, Brazil). After instrumentation, canals were rinsed with 5 mL of distilled water, dried using paper points (Dentsply Maillefer, Ballaigues, Switzerland) and filled with an epoxy resin root canal sealer (AH Plus, Dentsply DeTrey, Konstaz, Germany) using a Lentulo spiral (Dentsply Maillefer). A medium-sized #35, nonstandardized, gutta-percha cone was fitted at the working length, and a size #30 gutta-percha condenser (Dentsply Maillefer) was inserted into the root canal alongside the master cone without rotation to 2 to 3 mm from the working length to cause lateral condensation. Rotation of the condenser commenced at 5,000 to 8,000 rpm, with the condenser being maintained in the same position for 3 seconds and then slowly withdrawn from the canal as rotation continued. Excess gutta-percha was removed from the canal orifice, and the remainder was vertically condensed using a size #4 manual plugger (Dentsply Maillefer). The obturated teeth were radiographed (DSX 730, Owandy Dental Imaging, Champs sur Marne, France) at different angulations to verify the quality of filling procedure.

Postspace Preparation

Following root canal space obturation, the largest canal of each tooth was enlarged to receive one of the three sized endodontic fiber posts: #1, #2, or #3 (RelyX Fiber Post, 3M Oral Care, St. Paul, Minnesota, United States). This process was performed using the specific-sized postpreparation bur (3M Oral Care) in a slow-speed (15,000 rpm), air-driven handpiece (N270, Dabi Atlante, Ribeirão Preto, SP, Brazil) for 20 seconds. The canal was prepared to a distance ~4 mm below the bottom of the pulp chamber. Drilling removed all the gutta-percha materials and prepared the postspace. Cleaning of the canal was checked under microscopy (MC-M31, DFVasconcellos, Valença, RJ, Brazil) to verify if there were remnants of gutta-percha.

Table 1 Characterization of the treated teeth used in this study

Patient #	Tooth	Drilled canal	Postdrill #
1	Left mandibular second premolar	Facial	1
2	Left mandibular central incisor	–	2
3	Right mandibular first molar	Distal	3
4	Left maxillary second premolar	Lingual	3
5	Right maxillary first premolar	Lingual	3

Temperature Measurements

Immediately following drilling for postspace, a 1-cm long, autoclavable probe (MT-D Surface Microprobe, Physitemp Instruments Inc., Clifton, New Jersey, United States) containing a T-type thermocouple was placed so that the side of the tip end rested against the deepest portion of the prepared canal wall (►**Fig. 1**). The probe response time was 25 μs.

The probe was connected to a battery-powered (BP-1, Physitemp Instruments) analog to digital converter (Thermes USB, WFI, Physitemp Instruments Inc., Clifton, New Jersey, United States), which sent a digital Wi-Fi signal (16 samples/s) to a base-receiving unit (Thermes-IFC, Physitemp Instruments), attached to the USB port of a personal computer. System calibration (InstaCal, MC Measurement Computing, Norton, Massachusetts, United States) and data acquisition capability (TracerDAQ, MC Measurement Computing, Norton, Massachusetts, United States) were used to digitize the received temperature values, and an additional software (DasyLab Lite, V 11, MC Measurement Computing, Norton, Massachusetts, United States) provided an electronic strip chart recording of probe temperature with respect to time. The probe was certified as calibrated to NIST-traceable sources (National Institute of Standards and Technology, Gaithersburg, Maryland, United States) and was accurate to within ± 0.2°C with a resolution of 0.01°C within the range of interest (25–45°C).

Following this measurement, the probe was removed and placed in sterile, room temperature water to avoid rapid alterations in recorded temperature values arising from movement of air. The canal space was then irrigated using sterile saline (temperature of 23.8°C), and the probe was reinserted to the same length, and another temperature value

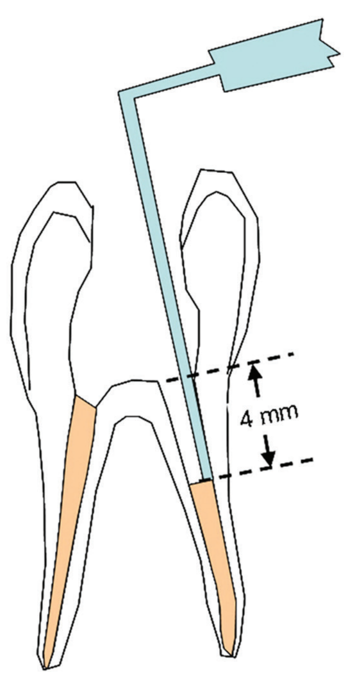

Fig. 1 Diagram showing thermocouple tip placement within root during the various stages of canal preparation. Only the lateral sides of the distal end of the tip provided temperature readings.

was recorded. The probe was removed, placed in water, and paper points (Dentsply Maillefer) were used to dry the canal space, immediately after which the probe was reinserted for another temperature measurement.

Finally, the probe was removed and water-stored for a duration of ~80 seconds, which simulates the duration of time required to mix and place self-adhesive cement and prepare the fiber post for insertion: cement was not placed into the canal—only this time was allowed to pass. At this moment, the probe was inserted to obtain the canal wall temperature immediately prior to a post being placed. The teeth were then temporarily restored using a provisional filling material (Coltosol, Coltène Whaledent, Altstätten, Switzerland) inside the root portion over which glass ionomer cement was placed (Ketac Molar Easymix, 3M Oral Care, St. Paul, Minnesota, United States). Each patient was then appointed for a definitive restoration procedure. The room temperature during the measurements and experiments was 23.8°C.

The logged temperature data were exported into a spreadsheet program (EXCEL 2003) and plotted. Temperature values correlating with the specific procedures of interest (following the end of postdrilling, after a saline rinse, subsequent to drying with a paper point, and immediately prior to postcementation) were then determined from the plotted time-based charts for each patient. Data were subjected to exploratory data analysis (Shapiro–Wilk and equal variance tests). Because the equality of variances, normal distribution of errors, and absence of outliers were satisfied, a parametric test was chosen. The mean temperatures for the individual treatment events among the various patients were compared using a one-way, repeated measures analysis of variance, and pair-wise values were compared using the Tukey's *post hoc* test. All statistical analyses were performed at a preset α of 0.05, using Sigma Plot V11.0, Systat Software, Chicago, Illinois, United States, on a personal computer.

Results

Normality and equal variance tests were passed ($p = 0.241$ and $p = 0.796$, respectively). Analysis of the results indicates that significant differences in measured canal wall temperatures existed among the preparation stages ($p < 0.001$). Temperature values during the various stages of treatment are summarized in ►**Table 2**. Data were tightly distributed about mean values, with coefficients of variation ranging from only 2.4 to 3.3%. *Post hoc* analysis revealed that temperature values of most treatment stages were significantly different; however, no significant difference was observed between temperature values when using the paper point (34.8 ± 1.1°C) and those immediately prior to postplacement (34.9 ± 1.2°C) ($p = 0.913$). The highest mean temperature was noted post drilling (35.5 ± 0.8°C), while the lowest was found following saline solution rinse (34.0 ± 0.9°C).

►**Fig. 2** presents the results obtained from the data recording of an individual patient, upon which the individual treatment steps are labeled on the temperature profiles recorded. From this figure, it can be observed that the canal

Table 2 Individual and mean (standard deviation) canal wall temperatures (°C) obtained during the different stages of canal postpreparation and statistical grouping of temperature values among treatment stages

Patient #	Following drill	Saline solution	Paper point	Prior to post
1	36.3	35.3	36.1	36.0
2	35.2	33.7	34.1	34.4
3	36.1	33.8	35.2	35.6
4	35.8	34.4	35.3	35.5
5	34.2	33.0	33.3	33.2
Mean	35.5 (0.8)A	34.0 (0.9)C	34.8 (1.1)B	34.9 (1.2)B

Means followed by different letters are significantly different ($p > 0.05$).

wall temperature is declining, immediately following drilling. Following saline rinsing, the temperature of the root surface increased data acquisition, which was becoming warmed by the underlying, higher temperature, intact root dentin. During the paper point insertion phase and prior to postplacement, a slight temperature increase was noted. Throughout the restorative process, canal wall temperatures were significantly lower than that of the body (~37°C) and were much greater than that of room temperature (23.8°C).

Discussion

The research hypothesis stating that no difference in the temperature of the root canal wall space would be found during various stages of preparation was rejected because temperature values of most treatment stages were significantly different. Temperature values used for analysis were determined by selecting the temperature value half way between initial temperature value and final one for each event. From ►**Fig. 2**, it can be observed that the canal wall temperature is declining, immediately following drilling. This decline is indicative that the interfacial friction between the cutting flutes of the bur and the root dentin causes a temperature increase, which, following the drill removal, results in cooling of the freshly cut dentin wall. Following saline rinsing, the temperature of the root surface increased during data acquisition, indicating that the saline cooled the root wall. However, temperature was becoming warmed by the underlying, higher temperature, intact root dentin. During the paper point insertion phase, only a slight temperature increase was noted. Immediately prior to post placement, the same small temperature increase was seen during data acquisition, but the temperature level appeared slightly greater than it did for only the paper point phase.

The implications of knowing the clinical canal wall temperature relate to the curing rate and extent of polymerization of self-adhesive resin cements that do not need separate acid etching, rinsing, drying, or application of dentin-bonding agents.[3,5,17] Because these steps would

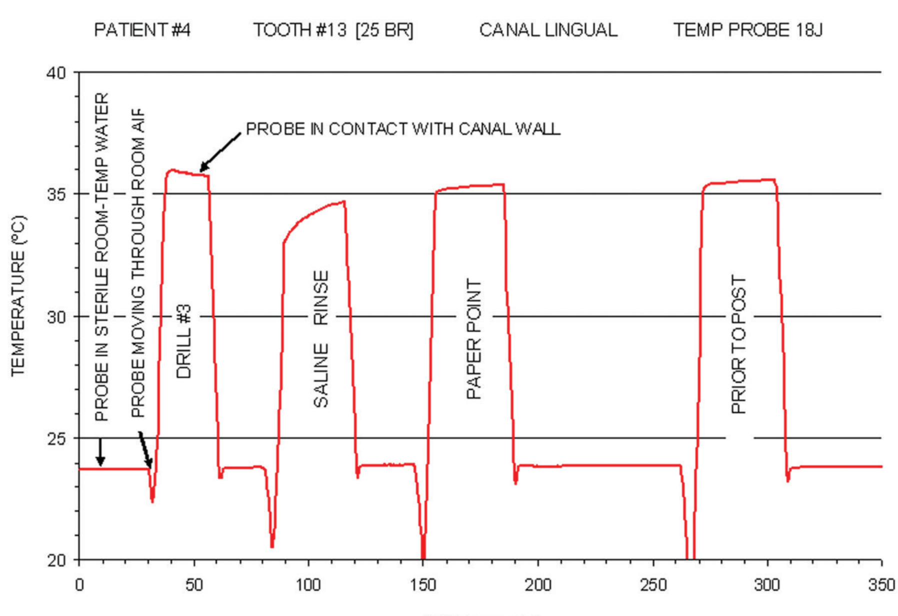

Fig. 2 Example of sequential temperature acquisition obtained during specific stages of postpreparation and precementation .

be eliminated when using self-adhesive resin cements, measurement of prepared canal wall temperature indicates the thermal environment, in which the thin film of resin cement would be surrounded while polymerizing. Previous works indicate that the temperature of resin composite significantly and positively affects the rate and extent of conversion, even between room temperature and 37°C,[10,11] as well as polymerization shrinkage strain.[12] Price et al tested the effects of some temperatures (22, 26, 30, and 35°C) and reported that a relatively small difference in temperature can have a large and significant effect on the rate and extent of polymerization of a dental resin.[11] Another study showed that temperature increase (from 23 to 37°C) had an effect on setting and shrinkage for resin cements.[12]

The finding of an in vivo, prepared root canal wall temperature of ~35°C indicates that the prepared root portion is warmer than that of the prepared coronal surface, that is, between 28 and 30°C, depending on the stage of restorative sequence.[10] This temperature suggested for the prepared root canal wall temperature indicates that in vitro testing should be performed near these values, to provide resins that polymerize similarly as they would intraorally. The values observed in the current study are ~35°C because other factors that can affect the temperature of canals walls, especially root dentine thickness, the type of roots, and the type of teeth.

Some studies have shown that the normal healthy adults' body temperature is estimated to vary between 36.1 and 37.2°C.[18,19] Thus, the canal wall temperature immediately prior to postcementation (34.9 ± 1.2°C) was lower than that of the average body temperature and much greater than that of room temperature (23.8°C). In fact, none of the confidence intervals established for standard errors about any of the mean temperature values for all treatments included body temperature within its range, indicating that all canal wall temperatures were significantly lower than body temperature. Room temperature was also not included within this range, indicating that the in vivo canal wall temperatures were well above that of the common laboratory environment.

One limitation of the study should be noted. A local anesthetic with vasoconstrictor was used when performing canal cleaning and obturation, and its effects were still present during the time of intracanal temperature measurements. Because blood flow to the tooth site was decreased,[20] it is possible that the temperature of the periodontal apparatus surrounding the tooth root was not at its normal, physiological temperature. Such a condition could have resulted in the temperatures observed in the current study to be less than if no anesthesia was used, when preparing the tooth for a post. Because some clinicians prefer to place their own posts following tooth treatment by an endodontist, they frequently do not anesthetize the teeth, a condition that would possibly lead to slightly higher temperatures than those recorded. However, use of block anesthesia seems to make no significance in pulpal blood flow in teeth distal to the injection site,[21] so the potential to cause lowered periodontal complex temperatures may only be pertinent if local, infiltration anesthesia is used.

Conclusions

This in vivo study found that root canal wall temperature varied during various stages of preparation prior to endodontic post.

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Conflict of Interest

None declared.

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