

A NEW IN-VITRO METHOD OF MEASURING INTRA-PULPAL TEMPERATURE

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RESUMO

O objetivo deste estudo *in-vitro* foi avaliar uma nova técnica de medição de temperatura intrapulpar. O aparato utilizado para tomada de medidas foi constituído por massa de modelar a 36°C como estrutura de suporte para os espécimes e um osciloscópio digital para gravação dos dados obtidos. O sistema descrito (MO) foi comparado a outros dois sistemas que consistiram num sistema de banho térmico para manutenção da temperatura associado ao uso do osciloscópio digital (WO) ou a um lock-in (WL) para gravação dos dados. As cavidades pulpares dos incisivos humanos utilizados neste estudo tiveram acesso endodôntico, foram preenchidas com pasta térmica e um termopar foi introduzido em contato com o tecido dental. Um laser do diodo de 960 nm com 5,7 J/cm² de densidade da energia foi aplicado sobre a superfície vestibular de esmalte por 10 segundos para induzir mudanças térmicas intrapulpare. Os dentes foram irradiados três vezes utilizando cada sistema. Os resultados foram analisados usando o teste T pareado com nível de significância $p < 0,05$. Os valores médios do aumento de temperatura obtidos para os sistemas WL, WO e MO foram respectivamente 7,8; 7,7 e 6,9°C. Não foram notadas diferenças estatísticas na comparação entre os sistemas WO e MO. Concluindo, a massa de modelar pode ser considerada uma alternativa ao banho térmico para manter os dentes na temperatura corpórea. Tem como vantagens ser uma técnica simples e rápida de ser realizada. O osciloscópio digital é um equipamento eficiente, compacto e simples de se usar.

Descritores: polpa dental, esmalte dental, medição de temperatura, termopar.

ABSTRACT

The purpose of this *in vitro* study was to evaluate a new technique to measure the pulpal temperature of teeth. Measurement apparatus was constituted by modeling clay at 36°C, as support structure for the specimens, and a digital recording oscilloscope (MO) was compared to two other systems which consisted of water bath and lock-in (WL) and water bath and digital oscilloscope (WO). The pulpal cavities of extracted human incisors were accessed and filled with thermal paste and a thermocouple was inserted in contact with the dental tissue. A 960 nm diode laser with 5.7 J/cm² of energy density was applied during 10 seconds over buccal enamel surface to induce thermal changes inside the pulp chamber. All teeth were irradiated three times in each system. The results were analyzed using two-population (paired) t-test. A value of $p < 0.05$ was considered significant. The average of the temperature increase for the WL, WO and MO systems were 7.8°C, 7.7°C and 6.9°C respectively. No statistically significant difference was obtained between the system WO compared to WL and WO compared to the MO. Concluding, the modeling clay may be considered an alternative to the water bath to maintain the teeth at body temperature. It has the advantages of being a simple and fast technique. The digital storage oscilloscope is an efficient and compact equipment for temperature recording and it is simple to use.

Keywords: dental pulp, enamel, heat, monitoring, temperature, thermocouple.

INTRODUCTION

The concern with the consequences of increasing pulp temperature caused by many proceedings has always been present in dentistry. Several studies reported the temperature changes during cavity preparations [1-4], polishing restorations [5,6], ultrasonic instrumentation [7], resin polymerization [8-10], light-enhanced bleaching [11] and laser application for caries prevention [12].

The heat generated in the dental tissue is transferred to adjacent or underlying structure by heat conduction. It has been reported that heat applied to the teeth induces expansion of the dentinal fluid and the pulp which causes an increase of the outward flow from the severed tubules and also affects the vessels in the pulp tissue [13]. If the increase in the pulp cavity is high enough, those alterations may lead to tissue necrosis [14]. For these reasons, important studies were made to establish the limits of the temperature that can be induced in the pulp chamber, without generating damage to its tissue [14,15].

The thermocouple is an instrument widely used in vitro studies to evaluate temperature changes inside the pulp chamber [8,11,16-22]. This device is constituted by two dissimilar metals joined at one end, which generate a net thermoelectric voltage that relates to the temperature difference between the measuring junction and the end connected to the measuring device.

In a clinical situation the dental elements are surrounded by other tissues which keep them at body temperature. Some studies were realized without reproduction of this condition, as Renneboog-Squilbin (1989) [23], Yu (1993) [17] and Chang (1998) [20] which measured the temperature changes of the teeth in the air and Turkmen (2000) [21] and Cavalcanti (2002) [22] which immersed the dental elements in a dental material without keeping them at body temperature. However, Trowbridge (1980) [24], Hannig & Bott (1999) [25] and White (2000) [26] used a water bath to maintain the temperature of the teeth constant during the experiment. Lauer (1900) [27] chose the 2% semi-solid agar embedded in a physiologic solution.

Another important aspect is that the measurement of the temperature changes in empty pulp chamber does not necessarily provide

accurate information on thermal events which will occur in the clinical situation [20]. As a consequence, the filling of the pulp chamber with pulp tissue [20], thermo-conductor paste [21, 25, 28] and water [11] have been related.

In vitro studies are widely related in the literature to investigate temperature changes in the pulp chamber. So, the methodology adopted needs to reproduce *in vivo* conditions with high fidelity and preferably it has to be a simple and reproductive method. For these reasons, the purpose of this study is to evaluate a new technique to measure the pulpal temperature of teeth.

MATERIALS AND METHODS

System comparison

Six extracted, intact permanent mandibular central incisors were selected and maintained in deionized water. After pumice prophylaxis, the pulp cavity was accessed through the lingual surface preparation and the pulp tissue was removed. The temperature changes were measured with a thermocouple type K with 0.005 inch diameter and with a time constant of 0.1 seconds (Omega Engineering Inc., USA). The thermocouple was inserted into the pulp chamber and fixed in contact with the dental tissue, under the area to be irradiated, with a small wooden wedge with 0.3 mm of width (Figure 1). Before the thermocouple insertion, the pulp cavity was filled with silicon thermal paste (KS-609, Shin-Etsu Chemical Co., Ltd., Japan) to improve the thermal contact between the sensor tip of the thermocouple and the dental tissue.

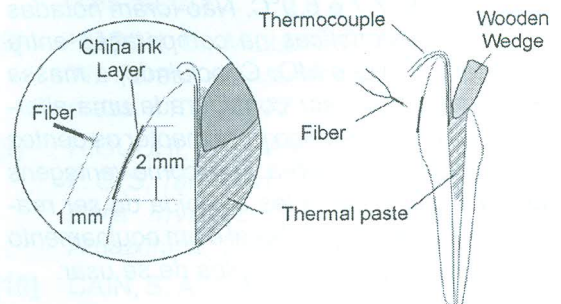


Figure 1 – Schematic drawing showing tooth preparation, thermocouple position and area to be irradiated.

The diode laser used in this study was developed at the Center for Lasers and Applications of the University of São Paulo. This laser emitted up to 15 Watt coherent radiation

at a wavelength of 960 nm. The operation mode used was "quasi-continuous" (qcw) and the parameters were 5 W of peak power, repetition rate of 6.5 Hz, pulse duration 10 ms, energy density per pulse of 5.7 J/cm² and time exposure of 10 seconds. Prior to the irradiation, a thin layer of china ink was applied in the enamel of the buccal surface covering an area of 2 x 2 mm above the thermocouple position. The 600 micron diameter fiber scanned the whole painted area about 1mm far from the enamel surface (Figure 1).

Table 1 – The three systems used to measure the temperature changes inside the pulp chamber

Group WL Water (W) and Lock in (L)
Group WO Water (W) and Digital oscilloscope (O)
Group MO Modeling clay (M) and Digital oscilloscope (O)

Three different systems were used to measure the changes of the temperature inside the pulp cavity, as shown in table 1, and all teeth were irradiated three times with each apparatus totalizing eighteen irradiations in each system. The water was maintained at 36°C by a water bath (Precision Scientific CO., Chicago, USA) and the teeth were positioned with the radicular portion immersed in the water (Figure 2).

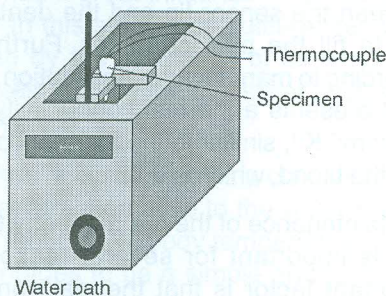


Figure 2 – Schematic drawing of the water bath and tooth placement in the water.

The modeling clay (Faber Castell, Brazil) was fixed on top of a copper plate, with its temperature adjusted to 36°C using a thermoelectric cooler (model CP2-12706L, Melcor, New York, USA) controlled by a programmable setpoint controller (model 2416, Eurotherm, UK)

and the teeth were embedded into the clay leaving the crown exposed (Figure 3). The temperature of the water vapor present 5 mm above the water bath at 36°C was measured to be 30°C and the temperature of the room was kept at 23°C during the experiment.

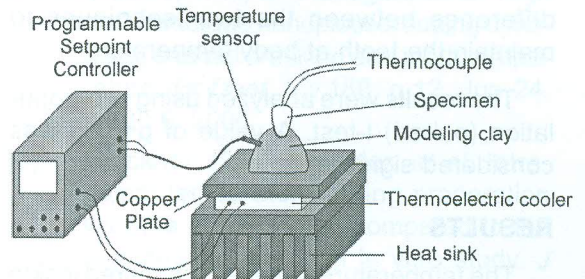


Figure 3 – Schematic drawing of the modeling clay setup.

The data collecting in the group WL was done by using thermocouples, a voltage amplifier (homemade amplifier with a gain of 800x), an analogue to digital converter (lock in amplifier, model 5RS10 Stanford Research System) and a laptop computer for storage of the data (Figure 4)

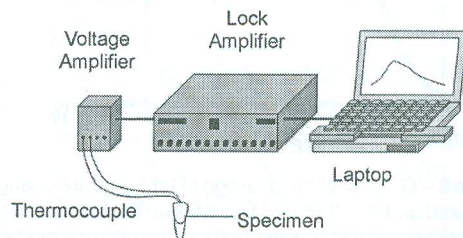


Figure 4 – Schematic drawing of lock in system.

In groups MO and WO, thermocouple was connected to a temperature converter (model TC-253, Beckman Inc., California, USA) coupled to a digital storage oscilloscope (model TDS360, Tektronix Inc., Oregon, USA), as shown in Figure 5.

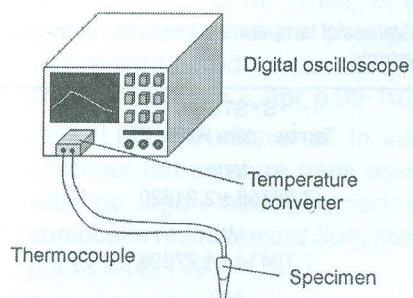


Figure 5 – Schematic drawing of digital oscilloscope.

Statistical analysis

The temperature changes of the WL were compared to the WO to evaluate if there is any difference between the equipments used to record the temperature. The registers from WO were compared to the MO to analyze the difference between the two techniques to maintain the teeth at body temperature.

The results were analyzed using two-population (paired) t-test. A value of $p < 0.05$ was considered significant.

RESULTS

The temperature changes measured inside the pulp chamber are shown in Figure 6. These values were obtained from the average of all measures with each system.

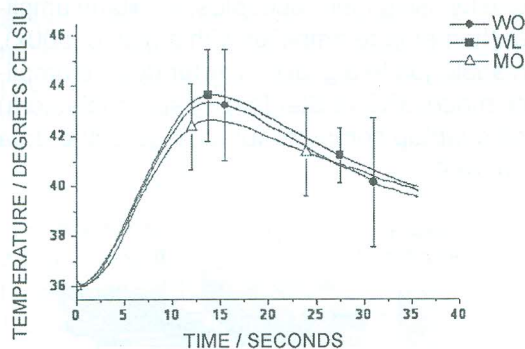


Figure 6 – Graphic of the average of temperature changes measured and the Standard Deviation in the systems water and oscilloscope (WO), water and lock-in (WL) and modeling clay and oscilloscope (MO).

The average of the temperature increase measured in each system is presented in Table 2. The paired t-test demonstrated that the changes occurred in the system WL compared to the WO ($p = 0.72122$) and the WO compared to the MO ($p = 0.08277$) are not significant at the $p < 0.05$ level.

Table 2 – Values of temperature increase (mean \pm sd), in each system.

SYSTEMS	Temperature Raise (°C)
WO	7.68756 \pm 2.21620
WL	7.79414 \pm 1.77398
MO	6.94666 \pm 1.96658

DISCUSSION

The mean temperature increases in all systems were higher than 5.5°C, which is considered safer [14]. Therefore, the diode laser was used in this study with the only purpose to induce thermal changes inside the pulp chamber.

Some aspects have to be considered when evaluating a system to measure intrapulpal temperature changes in vitro. The samples preparation is important to guarantee the correct placement of the probe. However, the teeth structure must be preserved at the most to allow more volume to dissipate heat [28]. In this study, the thermocouple was inserted into the pulp chamber through cavity preparation in the lingual surface. Despite the methodology of apical insertion of the probe [3, 19] the technique employed allowed the placement of the sensor tip in direct contact with the dentinal tissue under the area to be irradiated [29] and x-ray is not necessary to confirm the probe location. Aside from the location of the thermocouple, the filling of the pulp chamber has been shown to be of importance to the increase of the temperature. Chang & Wilder-Smith (1998) [20] considered the pulp tissue for this purpose. However, the methodology purposed seems to be complicated. In order to place the thermocouple it is necessary to remove the pulp tissue from vital teeth, keeping its integrity, and reinsert it after sensor tip placement. In this study we used a thermal conducting paste, which is simple to work with, to improve the contact between the sensor tip and the dental tissue and to fill the pulp chamber. Furthermore, according to manufacturer description, this material presents a thermal conductivity of 0.19 cal.s⁻¹.m⁻¹.K⁻¹, similar to the thermal conductivity of the blood, which is 0.13 cal.s⁻¹.m⁻¹.K⁻¹ [30].

Maintenance of the teeth at body temperature is important for several reasons. One important factor is that thermal conductivity varies according to the temperature. According to Peters & Augsburger (1981) [28], any changes that occur in the pulp chamber should apply to what occurs clinically and the reversal of the effect should occur at much the same rate. In this study two different methods were used and no significant difference between them was shown. However, the mean temperature increase using the water bath is higher than using

modeling clay, as seen in Figure 6, probably due to the fact that the water vapor present above the bath surface keeps the coronal portion of the tooth at 30°C. When using modeling clay, the crown was in contact with the air at 23°C (room temperature), which contributes to the heat dissipation. The later situation could simulate the presence of a high volume aspirator placed to the tooth during some treatments with the objective of ensuring adequate air flow over tooth surface to minimize pulpal temperature increase. Furthermore, modeling clay presents some advantages over water bath. The tooth is easily embedded into the clay, the temperature rise from ambient to 36 °C is faster due to the small material volume needed and it constitutes by itself a simpler and more compact arrangement.

Visuri (1996) [31] used a digital oscilloscope for the temperature record and Zezell (1996) [19] used an amplifier, lock in and a laptop for the same purpose. Both systems generated similar results and no statistical difference was showed. Digital storage oscilloscopes are nowadays compact and relatively cheap equipments with widespread use and therefore lend themselves perfectly for their use as a temperature recorder. They substitute voltage amplifier, analogue to digital converter, storage device and data display in one equipment.

Different thickness of enamel and dentin in the teeth used for the temperature measurements has a great influence in temperature rise [29]. In this study these differences were eliminated by the irradiation of all teeth with each system and by the statistical analysis in a paired t- tailed test.

In conclusion, the modeling clay should be considered an alternative to the water bath to maintain the teeth at body temperature. It has the advantages to be a simple and fast technique. The digital storage oscilloscope is an efficient and compact equipment to record temperature and is simple to use.

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