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Direct measurement of time-dependent anesthetized *in vivo* human pulp temperature

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ABSTRACT

Objectives. Human intrapupal tooth temperature is considered to be similar to that of the body (≈37 °C), although the actual temperature has never been measured. This study evaluated the *in vivo*, human, basal, coronal intrapulpal temperature of anesthetized upper first premolars.

Methods. After approval of the local Ethics Committee was obtained (protocol no. 255,945), upper right and left first premolars requiring extraction for orthodontic reasons from 8 volunteers, ranging from 12 to 30 years old, received infiltrative and intraligamental anesthesia. The teeth ($n = 15$) were isolated using rubber dam and a small, occlusal preparation was made using high-speed handpiece, under constant air–water spray, until a minute pulp exposure was attained. The sterile probe from a wireless, NIST-traceable, temperature acquisition system (Thermes WFI) was inserted directly into the coronal pulp. Once the probe was properly positioned and stable, real-time temperature data were continuously acquired for approximately 25 min. Data (°C) were subjected to 2-tailed, paired *t*-test ($\alpha = 0.05$), and the 95% confidence intervals for the initial and 25-min mean temperatures were also determined.

Results. The initial pulp temperature value (31.8 ± 1.5 °C) was significantly lower than after 25-min (35.3 ± 0.7 °C) ($p < 0.05$). The 95% confidence interval for the initial temperature ranged from 31.0 to 32.6 °C and from 35.0 to 35.7 °C after 25 min. A slow, gradual temperature increase was observed after probe insertion until the pulp temperature reached a plateau, usually after 15 min.

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Significance. Consistent coronal, human, *in vivo* temperature values were observed and were slightly, but significantly below that of body core temperature.

1. Introduction

Pulp health integrity is crucial to any restorative treatment, and is a clinical challenge, because teeth are subjected to trauma by heat generated during restorative procedures, such as from use of high and low speed handpieces [1], restorative materials with exothermic setting [2], restoration finishing and polishing [3], as well as from application of high power light emitting diode (LED) curing units and laser sources to polymerize resin-based materials [4]. For these reasons, the consequences of heat, or other external stimuli, on pulp chamber temperature have been investigated [4,5].

Initial *in vivo* effects of heat on pulp temperature (PT) and its biological consequences were performed by Zach and Cohen in 1965 [6]. In that study, a 5.5 °C PT increase in *rhesus* monkeys, from application of a hot metal source to the facial enamel surface, induced necrosis in 15% of evaluated pulps. Because of the high expense of animal testing, *in vitro* techniques using extracted teeth were developed to evaluate pulp chamber temperature change under simulated clinical conditions, while applying various external heat sources [5,7,8]. In these reports, the pulp chamber temperature, prior to application of temperature-raising effects, was pre-set at 37 °C (human body temperature) [5,7,9], or at room temperature [4], or was not mentioned in the study [10,11]. Others simulated the influence of pulpal blood flow *in vitro*, to evaluate how this parameter might dissipate internal tooth heat generated by exposure to dental light curing units [5,12,13]. Conversely, these studies set the initial, baseline pulp chamber fluid temperature between 33 °C and 34 °C [13], or between 34 °C and 35 °C [12]. Using a finite element model, along with *in vitro* simulation of restorative procedures, a simulated temperature excursion at the pulp–dentin junction during photocuring of a dental restoration was calculated [14]. In that study, the authors observed that some exposure protocols may cause potentially dangerous PT increase, mainly when using high intensity lights, or when curing a thin resin layer. Although such studies provide important information regarding the effects of external heat sources on the temperature increase in *ex vivo* human tooth pulps, it is evident that accurate data on the thermal effects of such heat sources will depend on the actual *in vivo* temperature of human pulp tissue. However, no literature concerning *in vivo* baseline temperature of the human pulp can be found.

The purpose of this *in vivo* study was to develop a method to measure the baseline PT of locally anesthetized, human upper premolars. The research hypotheses were that (1) consistent and reproducible intrapulpal temperature values can be obtained using a well-controlled measurement system, and that (2) the *in vivo* temperature of locally anesthetized human pulp tissue is similar to that of the human body (the baseline temperature from which subsequent temperature rise values could be measured).

2. Materials and methods

2.1. Study design

The study design was approved by the Ethics Committee at State University of Ponta Grossa (protocol no. 255,945). Eight volunteers, ranging from 12 to 30 years, requiring extraction of upper right and left first premolars for orthodontic reasons were selected from the Orthodontic specialization program in Ponta Grossa, Brazil, were recruited in February, 2013, and attended to between March and April, 2013. Patient inclusion criteria included: (1) treatment plans indicating premolar extractions for orthodontic reasons, (2) the presence of healthy, intact, non-carious, and non-restored, fully erupted treatment teeth, and (3) patients with well-controlled health conditions that allowed all procedures involved in the research to be performed with minimal risk. Exclusion criteria included (1) those patients who did not agree to volunteer for the study, (2) patients not meeting all of the inclusion criteria.

2.2. Intrapulpal temperature measurement

After written consents were obtained, each study volunteer received local, infiltrative and intraligamental anesthesia, using approximately 1.8 ml of 2% Mepivacaine Hidrocloryde (36 mg) with 1:100,000 epinephrine (18 μg) (Mepiadre, Nova DFL Industria e Comercio, Rio de Janeiro, RJ, Brazil), and the teeth ($n = 15$) were isolated using rubber dam, one at a time. As there is no previous human study to base sample size on, the present study was used as its own pilot. A small, occlusal preparation was made, using a round diamond bur (no. 1015, KG Sorensen, Cotia, SP, Brazil) in a high-speed handpiece, under air–water spray, until the preparation floor was near the buccal pulp horn (Fig. 1a). Then, a small, pencil-shaped diamond bur (no. 2134, KG Sorensen) was used to produce a minute pulp exposure, with no pulp bleeding (Fig. 1b). Care was taken to ensure that the same water flow and air pressure were used for each tooth, as well as the same time for each preparation. A wireless, NIST-traceable, temperature acquisition system (Temperature Data Acquisition—Thermes WFI, Physitemp, Clifton, NJ, USA) was used to measure PT. Two probes were connected to that system and both were immersed in a 0.9% sterile saline solution at room temperature (RT), while the tooth was prepared. After pulp exposure, one probe was removed from water storage, inserted into the pulp chamber, and positioned to remain stable while PT was recorded in real-time (Fig. 1c). A small groove was created on the buccal cusp, close to the cusp tip (Fig. 1d), to allow the probe to rest on the cusp tip and ensure that the 1-cm long probe tip penetrated approximately 4 mm into the pulp chamber: in a similar position for all teeth (Fig. 1e). The other probe remained in the RT saline solution (approximately 22.0 °C), as a reference. Room temperature was stable and controlled by air