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In vivo temperature rise in anesthetized human pulp during exposure to a polywave LED light curing unit

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ABSTRACT

Objectives. This *in vivo* study evaluated pulp temperature (PT) rise in human premolars during exposure to a light curing unit (LCU) using selected exposure modes (EMs).
Methods. After local Ethics Committee approval, intact first upper premolars, requiring extraction for orthodontic reasons, from 8 volunteers, received infiltrative and intraligamental anesthesia. The teeth ($n = 15$) were isolated using rubber dam and a minute pulp exposure was attained. A sterile probe from a wireless, NIST-traceable, temperature acquisition system was inserted directly into the coronal pulp chamber, and real time PT (°C) was continuously monitored while the buccal surface was exposed to polywave light from a LED LCU (Bluephase 20i, Ivoclar Vivadent) using selected EMs allowing a 7-min span between each exposure: 10-s either in low (10-s/L) or high (10-s/H); 5-s-turbo (5-s/T); and 60-s-high (60-s/H) intensities. Peak PT values and PT increases from baseline (ΔT) after exposure were subjected to one-way, repeated measures ANOVAs, and Bonferroni's *post hoc* tests ($\alpha = 0.05$). Linear regression analysis was performed to establish the relationship between applied radiant exposure and ΔT.
Results. All EMs produced higher peak PT than the baseline temperature ($p < 0.001$). The 60-s/H mode generated the highest peak PT and ΔT ($p < 0.001$), with some teeth exhibiting ΔT higher than 5.5 °C. A significant, positive relationship between applied radiant exposure and ΔT ($r^2 = 0.916$; $p < 0.001$) was noted.

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Significance. Exposing intact, *in vivo* anesthetized human upper premolars to a polywave LED LCU increases PT, and depending on EM and the tooth, PT increase can be higher than the critical ΔT, thought to be associated with pulpal necrosis.

1. Introduction

The great challenge for clinicians performing restorative procedures with resin composites is to reestablish tooth form and function in a short time and causing the least pulp trauma. Because heat is considered a primary cause of pulpal injury [1], the heat generated during some dental procedures may be causative factors: use of high and low speed handpieces, restorative materials with exothermic setting reactions [2–4], polishing techniques of such materials [5], as well as tooth exposure to light from either quartz–tungsten–halogen or light emitting diode (LED) light curing units (LCU) [4,6–12]. Recently, the heat caused by light emitted by LED LCUs on prepared teeth has become an issue, because LED LCUs with radiant emittance values exceeding 2000 mW/cm^2 are now commercially available.

In an attempt to predict the thermal stimuli caused by light emitted by LCUs on teeth and to determine the relationship between radiant emittance and temperature rise into the pulp chamber, several *in vitro* studies measured the temperature rise during exposure to LCUs with thermocouples inserted into the pulp chamber of extracted teeth [4,6–12]. Overall, the temperature increase observed during these exposures ranged from 1.5 to 23.2 °C. Such a wide range of temperature increase reported in literature is clearly related to different experimental approaches, LCUs, radiant emittance, and radiant exposure. For instance, some studies evaluated the increase in pulp chamber temperature in intact premolars and molars [7,11,13], while others tested anterior teeth: incisors, lateral, and canines [6,10]. In addition, among the *in vitro* studies that evaluated posterior teeth, some investigators measured pulp temperature (PT) increase on teeth having occlusal or occlusal-proximal preparations prior to exposure to LCU light [8,11]. Moreover, in an attempt to evaluate the influence of resin-based restorative materials, other studies also included restorative procedures using resin composites during PT change analysis [11,14,15]. Based on these reports, there is a consensus that the use of some LED LCUs can result in a pulp chamber temperature rise to values higher than the threshold temperature increase of 5.5 °C, considered harmful for the pulp [16].

One of the most important aspects regarding the effects of LCU exposure on PT increase is to establish an accurate relationship between light exitance or radiant exposure and PT increase. In order to achieve that, an accurate beam profile analysis of the light emitted by the LCU is required so these parameters can be precisely determined. In this regard, most *in vitro* studies evaluating PT increase focused only on comparing a variety of LCU brands and models, and conventional, hand-held dental curing radiometers were used to provide a "guesstimate" radiant exposure [8,11,14], or even no light exitance was measured [10,15]. In addition, even in studies that precisely measured LCU output [7], the differences in light beam profile from each LCU do not allow clear conclusions about a relationship between radiant exposure and PT increase. For this reason, although evidence in the literature clearly indicates that light emitted by LED LCUs can be harmful to the pulp, the relationship between radiant exposure and PT increase is still unclear.

Despite evidence that high-intensity LCUs can increase pulp chamber temperature, one must consider that *in vitro* conditions do not reproduce the complexities of an *in vivo* scenario. For example, most *in vitro* studies did not simulate the influence of the dental pulp. This tissue is highly vascularized and contains the main regulatory system for heat distribution in teeth, capable of dissipating the heat transferred by external thermal stimuli to the dentin/pulp complex [9,17]. Even *in vitro* studies that simulate pulp flow [6,9] were not capable of reproducing the dynamic changes in pulp fluid flow, when temperature changes in this tissue occur [18]. Indeed, because any external thermal stimuli can change the fluid movement either inward or outward from the pulp depending on the stimuli, it is important to consider that the actual *in vivo* pulp regulatory system may be more effective in dissipating external heat than would be a simulated pulp flow condition. However, no information is available in the literature regarding the *in vivo* temperature increase within the human pulp when teeth are exposed to light from a high intensity LED LCU.

The purpose of this *in vivo* study was to evaluate PT increase of anesthetized, vital, unrestored, human upper premolars during exposure to a polywave, LED-based, dental light curing unit, applying varying values of radiant exposure. The tested alternative hypotheses were that (1) all exposure modes (EM) of the LCU will produce a significant PT increase over that of the baseline temperature values; (2) none of the applied EMs will produce a PT increase higher than the potentially harmful threshold temperature increase of 5.5 °C; and (3) there is a direct, positive relationship between applied radiant exposure and PT increase.

2. Materials and methods

2.1. *In vivo* measurement of pulp temperature increase

This study was approved by the Ethics Committee at the State University of Ponta Grossa (protocol # 255,945). Eight volunteers, ranging from 12 to 30 years, requiring extraction of upper right and left first premolars ($n = 15$) for orthodontic reasons, were selected from the Orthodontic specialization program in Ponta Grossa, Brazil. All patients were recruited in February 2013, and were attended to between March and April 2013. Patient inclusion criteria included (1) treatment