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Influence of Class V preparation on *in vivo* temperature rise in anesthetized human pulp during exposure to a Polywave® LED light curing unit

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ABSTRACT

Objective. This *in vivo* study evaluated pulp temperature (PT) rise in human premolars having deep Class V preparations during exposure to a light curing unit (LCU) using selected exposure modes (EMs).

Methods. After local Ethics Committee approval, intact first premolars ($n = 8$) requiring extraction for orthodontic reasons, from 8 volunteers, received infiltrative and intraligamental anesthesia and were isolated using rubber dam. A minute pulp exposure was attained and sterile probe from a wireless, NIST-traceable, temperature acquisition system was inserted into the coronal pulp chamber to continuously monitor PT (°C). A deep buccal Class V preparation was prepared using a high speed diamond bur under air-water spray cooling. The surface was exposed to a Polywave® LED LCU (Bluephase 20i, Ivoclar Vivadent) using selected EMs, allowing 7-min span between each exposure: 10-s in low (10-s/L), 10-s (10-s/H), 30-s (30-s/H), or 60-s (60-s/H) in high mode; and 5-s-Turbo (5-s/T). Peak PT values and PT increases over physiologic baseline levels (ΔT) were subjected to 1-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 ($p < 0.001$). Only 60-s/H mode generated an average ΔT of 5.5 °C ($p < 0.001$). A significant, positive relationship was noted between applied radiant exposure and ΔT ($r^2 = 0.8962$; $p < 0.001$).

Significance. *In vivo* exposure of deep Class V preparation to Polywave® LED LCU increases PT to values considered safe for the pulp, for most EMs. Only the longest evaluated EM caused higher PT increase than the critical ΔT, thought to be associated with pulpal necrosis.

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1. Introduction

Over the last decades, powerful light emitting diode (LED) light curing units (LCU) have become available in order to provide optimal mechanical properties of photoactivated, resin-based composites and to reduce the time required for clinicians to accomplish restorative procedures. In this context, LED LCUs with radiant emittance values exceeding 2000 mW/cm^2 are now commercially available. Thus, the heat generated in target tissues by such devices has become an issue.

In a study using *Rhesus* monkeys, Zach and Cohen [1] concluded that a temperature increase of 5.5 °C within the pulp may lead to a high occurrence of pulpal necrosis. Subsequent to that work, several *in vitro* studies demonstrated that exposure to light emitted from second and third generation LED LCUs cause a significant temperature increase within the pulp chamber of extracted teeth, ranging from 1.5 to 23.2 °C [2–8]. Although this temperature rise range depends on LCU type, radiant emittance, and tooth characteristics [3–12], there is a consensus that the use of some LED LCUs can result in a pulp temperature (PT) rise to values close to, or even higher than, the potential damaging threshold temperature increase of 5.5 °C.

Most recently, in an attempt to clarify the relationship between radiant exposure values and pulp temperature, Runnacles et al. [13] evaluated the *in vivo* pulp temperature (PT) rise after a variety of radiant exposure values and exposure modes (EM) were delivered to the buccal surface of intact, human premolars. In that study, although all tested exposure modes caused significant PT rise in anesthetized human premolars over physiologic values, the most commonly used radiant exposure values did not cause higher temperature rise than the threshold temperature increase of 5.5 °C. Yet, in that study, only exposure to light with irradiant emittance of 1244 mw/cm^2 for 60 s (75 J/cm^2) caused a PT rise close to 5.5 °C. However, that study was performed on healthy, intact premolars, which only reproduces specific clinical situations, such as in-office bleaching procedures or when ceramic laminates or direct composite lamination procedures are applied to intact teeth. Therefore, those results cannot be extrapolated to the clinical scenario, where a deep preparation is formed after caries removal, leaving only a thin remaining dentin layer to protect the pulp against heat generated by light emitted from LED LCUs. Several *in vitro* studies show the importance of the thickness of remaining dentin in reducing the temperature rise within the pulp chamber during exposure to light emitted from LCUs [5,9,14,15]. For this reason, one could expect higher PT increase in the clinical scenarios where only a thin dentin wall remains at the bottom of a cavity preparation, in comparison to those values observed in intact, sound teeth. However, no information is available about the *in vivo* PT rise after exposure of premolars having a deep Class V preparation to light emitted from a third generation LED LCU.

The current study is one in a series of *in vivo* studies performed in humans, which evaluated the PT increase during exposure to light emitted from LED LCU under different clinical scenarios. In this sequence, *in vivo* PT rise was evaluated in premolars having deep Class V preparations during exposure to light emitted from a high power Polywave® LED LCU. The research hypotheses tested were that (1) all exposure modes will cause a significant increase in pulp temperature compared to baseline, physiologic temperature, that (2) none of the evaluated EMs causes PT rise to higher than those considered harmful (5.5 °C) to the pulp tissue, and (3) that there is a direct, positive relationship between radiant exposure application and PT rise.

2. Materials and methods

2.1. *Radiant emittance measurement and radiant exposure calculation of the LCU*

The spectral power emission from the tested polywave LED LCU (bluephase® 20i, Ivoclar Vivadent, Schaan, Liechtenstein) was recorded five times each, using a laboratory grade spectroradiometer (USB 2000, Ocean Optics, Dunedin, FL, USA) and a 6-in integrating sphere (Labsphere, North Sutton, NH, USA), previously calibrated using a NIST-traceable light source. The LCU tip end was positioned at the entrance of the integrating sphere, such that all light emitted from the unit was captured. The following exposure modes (EM) were evaluated: low, high, and Turbo. Wavelength-based, spectral power emission during each EM was determined using software (SpectraSuite v2.0.146, Ocean Optics) between 350 to 550 nm, which also provided a total of emitted power within that wavelength range. The optical emitting area of the distal end of the light guide was calculated, and this value was divided into the integrated spectral power value to derive the total radiant emittance from the curing light for each EM (mW/cm^2).

2.2. *In vivo measurement of PT increase*

After approval by the Ethics Committee at the State University of Ponta Grossa (protocol #255,945), 8 volunteers, between the ages of 13 and 20 years, were referred by the orthodontic specialization program in Ponta Grossa (Brazil) for extraction of either upper or lower first premolars (n = 8) for treatment reasons. The patients were recruited according to the demand and were attended to between May, 2013, and May, 2015. The inclusion criteria included (1) orthodontic treatment plan including upper or lower first premolar extractions, (2) the presence of fully erupted, intact teeth, with absence of caries and restorations, and (3) patients with well-controlled health conditions to reduce risks during the research procedures. Patient exclusion criteria included those individuals who did not agree to volunteer for the study or did not meet the study parameters.

After patient informed consent was obtained, the teeth received both infiltrative as well as intraligamental injections using a local anesthetic (2% Mepivacaine Hydrochloride with Epinephrine, Mepiadre, DFL Industria e Comercio, Rio de Janeiro, RJ, Brazil). Tooth preparation for intrapulpal temperature measurement was performed as previously described by Runnacles et al. [13,16]. A small, occlusal preparation was made in the center of the selected tooth, using a round diamond bur (#1015, KG Sorensen, Cotia, São Paulo, Brazil) in a high speed handpiece, with controlled amounts of air–water spray, until the preparation pulpal floor was near the buccal