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Analysis of temperature increase in swine gingiva after exposure to a Polywave® LED light curing unit

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ABSTRACT

Objective. This study evaluated the temperature increase in swine gingival temperature after exposure to light emitted by a Polywave® LED light curing unit (LCU, Bluephase 20i, Ivoclar Vivadent).

Methods. After local Ethics Committee approval (protocol 711/2015), 40 pigs were subjected to general anesthesia and the LCU tip was placed 5 mm from the buccal gingival tissue (GT) close to lower lateral incisors. A thermocouple probe (Thermes WFI, Physitemp) was inserted into the gingival sulcus before and immediately after exposure to light. Real-time temperature (°C) was measured after the following exposure modes were applied: High Power (20s-H, 40s-H, and 60s-H) or Turbo mode (5s-T), either with or without the presence of rubber dam (RD) interposed between the LCU tip and GT (n = 10). The presence of gingival lesions after the exposures was also evaluated. Peak temperature (°C) and the temperature increase during exposure over that of the pre-exposure baseline value (ΔT) data were analyzed using 2-way ANOVA followed by Bonferroni's post-hoc test ($\alpha = 5\%$). A binary logistic regression analysis determined the risk of gingival lesion development.

Results. Without RD, no significant difference in ΔT was observed among 20s-H, 40s-H, and 60s-H groups, which showed the highest temperature values, while the 5s-T exposure showed the lowest ΔT, regardless of RD. RD reduced ΔT only for the 20s-H group ($p = 0.004$). Gingival lesions were predominantly observed using 40s-H, with RD, and 60s-H, with and without RD.

Significance. Exposure to a LCU light might be harmful to swine gingiva only when high radiant exposure values are delivered, regardless of the use of RD.

1. Introduction

Light emitting diode (LED) light curing units (LCU) have become one of the most important tools in the clinicians' routine. Although earlier LED LCU generations were considered "cool" lights because they generated less heat than did quartz-tungsten-halogen (QTH) lamps [1–5], later, more pow-

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erful LCU versions were capable of generating as much heat as QTH sources [4,6–8]. Most recently, a new generation of LED lamp has been introduced. Different from the previous generations, these polywave® or "dual-peak" (multi-wave, multi-peak) LCUs emit light a broader wavelength range [9] to activate not only traditional photoinitiators, such as camphorquinone, but also alternative photoinitiators [10,11]. In addition, seeking more efficiency in the monomer-polymer conversion of resinous compounds and reduction of clinical time, these devices are capable of emitting light over 2000 mW/cm^2. As a consequence, more heat is generated during the resin polymerization, resulting in a considerable increase in the temperature inside the pulp chamber [3,12] and within the pulp tissue itself [13].

Although *in vitro* and *in vivo* studies have provided important information about the effects of light emitted by LCUs on pulp temperature [3,12,13] and histological changes caused by such a temperature increase within the pulp tissue [14,15], the deleterious effects of heat generated from LED LCUs, and exothermic polymerization of resin composites on the pulp, should not be the only concern for the clinician. Some restorative procedures utilizing light-cured resin composites are usually performed in close proximity to soft tissues, when restorations are located near the gingival margin. As a consequence, studies demonstrate the potential of some LED devices to burn soft tissues [16], affecting fibroblasts [17] and decreasing cell proliferation *in vitro*, irradiance and exposure duration [18]. In addition, other studies demonstrate that thermal injury can cause bone resorption and even necrosis [19,20]. For these reasons, although one could expect that the use of rubber dam over the gingival tissue would protect the soft tissue underneath from the blue light and subsequent heat generated during the tooth exposure, it is reasonable to expect that heat generated by these devices may harm gingival tissues as well [21,22]. In this regard, manufacturers have recommended that clinicians should not expose soft oral tissues at close proximity for long exposure periods [23]. However, no information regarding the thermal effects caused by exposure to LCUs on soft tissues and the protective effect of rubber dam is available in the literature.

In vivo tests on swine tissues have become an alternative research model, because this animal has similar physiology to human tissues, similar pathological conditions, and sufficiently similar tooth anatomy [24]. Most importantly, the width of attached gingiva is also similar to that in humans [25], and because pigs also have heterodont dentition, swine are also considered an appropriate model to conduct studies of tooth morphogenesis [26]. For these reasons, the pig is an animal of great value as a preclinical model, allowing the analysis of pathologies and oral changes [27,28].

Thus, the purpose of this *in vivo* study was to evaluate the effects of light emitted by a high power, dual-peak LED LCU on the temperature of swine gingival tissue exposed to a LCU light with varying exposure modes, either with rubber dam interposed between the gingiva and LCU tip or not. In addition, the presence of a gingival lesion caused by exposure to the LCU light was also addressed. The research hypotheses were: (1) exposure to light emitted from high intensity LED LCU causes temperature rise in gingival tissue; (2) gingival exposure to a LCU causes a visible lesion, regardless of radiant exposure value; and (3) the use of rubber dam reduces temperature rise in the gingival tissue as well as the potential for development of gingival lesions after exposure to a LCU.

2. Material and methods

2.1. Spectral analysis of light emitted by the LED LCU

The LCU used in the study was a commercially available, Polywave® unit (Bluephase 20i, Ivoclar Vivadent, Schaan, Liechtenstein). The spectral power values of High and Turbo exposure modes (EM) were recorded using a laboratory grade spectroradiometer (USB 2000, Ocean Optics, Dunedin, FL, USA) connected to a 6-in integrating sphere (Labsphere, North Sutton, NH, USA), previously calibrated using a NIST-traceable light source. The LCU tip end was held 5 mm distant from the aperture of the integrating sphere, either with or without the rubber dam interposed between the LCU tip and the entrance of the integrating sphere, so all light emitted from the unit was captured (n = 5). This distance simulated that observed clinically as imposed by the blue blocker tip ring. Wavelength-based, spectral power emission between 350 to 550 nm during each EM was recorded using software (SpectraSuite v2.0.146, Ocean Optics), which also provided the total emitted power value for 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 High and Turbo EM (mW/cm^2). This value was then multiplied by the light exposure duration to derive the value of radiant exposure applied to each exposed gingival surface for each light output mode (J/cm^2).

2.2. Animal preparation

This study was approved by the local Ethics Committee for use of Animals in Research (protocol 711/2015). Forty male pigs, having similar body weight (20–30 kg) and obtained from the discipline of Operative Techniques and Experimental Surgery in the graduate program in Medicine at the State University of Ponta Grossa were used. These pigs underwent major surgical procedures previously scheduled as part of the graduate program. Thus, no animal was used for the sole purpose of this study.

Under the care of a veterinarian, the animals received intramuscular administration of Ketamine (14 mg/kg), Xylazine (0.2 mg/kg), and Acepromazine (0.4 mg/kg), followed by endovenous administration of propofol (5 mg/kg). After oro-tracheal intubation, the animals received mechanical ventilation and were monitored with pulse oximetry. Maintenance was performed with inhalation anesthesia using isoflurane at a minimum alveolar concentration of 1.2–1.7%.

2.3. Baseline temperature of the gingival tissue

The cervical regions of the buccal surfaces of lower right and left lateral incisors were evaluated, to simulate light exposure on a Class V during a restorative procedure (Fig. 1a and b). Two gingival sites were evaluated per pig, resulting in a total of 80