



Full length article

Effects of blue diode laser (445 nm) and LED (430–480 nm) radiant heat treatments on dental glass ionomer restoratives

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ARTICLE INFO

Article history:

Received 14 June 2017

Received in revised form 25 July 2017

Accepted 5 September 2017

Available online xxxx

Keywords:

Blue diode laser

Light emitting diode

Glass ionomer cement

Water sorption

Solubility

Surface roughness

ABSTRACT

The purpose of this *in vitro* study was to evaluate the effect of two radiant heat treatments on water sorption, solubility and surface roughness of three conventional glass ionomer cements by using a blue diode laser (445 nm) and a light emitting diode (LED) unit (430–480 nm). Thirty disk-shaped specimens were prepared for each tested GIC (Equia Fil, Ketac Universal Aplicap and Riva Self Cure). The experimental groups ($n = 10$) of the study were as follows: Group 1 was the control group, in Group 2 the specimens were irradiated for 60 s at the top surface using a LED light-curing unit and in Group 3 the specimens were irradiated for 60 s at the top surface using a blue light diode laser. Statistical analysis was performed using one-way ANOVA and Tukey *post hoc* tests at a level of significance of $\alpha = 0.05$. Radiant heat treatments with both laser and LED devices significantly decreased water sorption and solubility ($p < 0.05$) of most of the tested GICs. Blue diode laser treatment was seemed to be more effective compared to LED treatment for some of the tested materials. There were no changes in surface roughness of the GICs after the treatments ($p > 0.05$). Among the tested materials there were differences in water sorption and solubility ($p < 0.05$) but not in surface roughness ($p > 0.05$). The use of the blue diode laser for this radiant heat treatment was harmless for the surface of the tested GICs and may be advantageous for the longevity of their restorations.

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1. Introduction

Laser diodes are electrically pumped semiconductor lasers in which the active laser medium is formed by a p-n junction of a semiconductor diode similar to that found in light-emitting diodes (LEDs). Currently, various new applications for diode lasers have been introduced in dentistry such as applications in periodontology [1], soft tissue surgery [2], endodontics [3], implantology [2] and tooth bleaching [4]. Due to the small size and low cost of the units and their easy handling they became popular to dental clinicians. Diode wavelengths used to range from 810 to 1100 nm and as a result they were poorly absorbed by soft tissue, and were not used for cutting or ablation [5].

A blue laser is a laser that emits electromagnetic radiation with a wavelength between 360 and 480 nm, which the human eye sees as blue or violet. Recently, blue diode lasers which emit light at 445 nm have been introduced for dental applications. Blue diode

lasers provide interaction with the soft tissues in the oral cavity [6] in such a way that the wavelength of the radiation coincides with the highest absorption in hemoglobin and melanin [7]. Considering that cutting power of a laser beam depends on the amount of energy absorbed by the tissue and that oral soft tissues are rich in hemoglobin and melanin, the blue diode lasers enable very fast, precise and painless cutting in oral surgery [8]. Blue lasers have been indicated in dentistry for ablation and incision of soft tissues [8], reduction of periodontal disease-causing bacteria [9] and in-office tooth bleaching [10]. Additionally, a blue laser-treatment has been suggested for the improvement of some properties of dental glass ionomer cements (GICs), which is attributed to thermo-catalysis of their setting reaction. As a matter of fact, Dionysopoulos et al. [11] reported that after radiant heat treatment with a blue diode laser, a significant increase in surface hardness of conventional GICs was observed.

Conventional GICs are commonly used for dental restorations due to their beneficial properties such as anticariogenic activity [12], chemical adhesion to dental tissues [13], and good biocompatibility [14]. However, they present higher solubility and water sorption as well as lower mechanical properties compared to

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resin-based restorative materials, which are mainly attributed to the nature of their setting reaction and composition [15]. Aiming to overcome the above disadvantages of conventional GICs, it has been proposed to deliver thermal energy by using dental light-curing units (such as dental LED units) on the surface of the GIC restorations, catalyzing their initial setting reaction [16]. Previous studies reported increased surface hardness of the glass ionomer materials [17–20], which may indicate clinical improvement of the behavior of their restorations such as increased wear resistance.

Water sorption and solubility of a restorative material influence its mechanical strength, color stability and wear resistance [21]. These physical properties of a conventional GIC are depended on composition and rate of the setting reaction. As a result, acceleration and improvement of the setting reaction of GICs by providing thermal energy may be advantageous for their physical and mechanical properties [16,19]. Moreover, it is of great importance to confirm the safety of this application on the integrity of the surface of the restorations [11].

Therefore, the aim of this *in vitro* study was to evaluate the effect of two radiant heat treatments on water sorption, solubility and surface roughness of three conventional GICs by using a blue diode laser (445 nm) and a light emitting diode (LED) unit. The novelty of the study was that the use of the blue diode laser for this treatment has never been investigated before regarding these properties.

Four null hypotheses were formulated prior to the study: the first null hypothesis was that radiant heat treatments did not affect water sorption and solubility of the tested materials; the second null hypothesis was that radiant heat treatments did not influence surface roughness of the tested GICs; the third null hypothesis was that blue diode laser and LED treatments exhibited the same behavior on the properties of the tested materials; and the fourth null hypothesis was that among the tested GICs there were no differences in their properties after the radiant heat treatments.

2. Materials and methods

2.1. Materials

Three conventional GICs of the same shade (A3.5) were investigated in this study (Equia Fill – EF, Ketac Universal Aplicap – KU and Riva Self Cure – RV). The technical characteristics of the tested materials are presented in Table 1.

2.2. Preparation of specimens

Thirty disk-shaped specimens were prepared for each tested material using cylindrical Teflon molds in room temperature ($23 \pm 1^\circ\text{C}$), resulting in 90 specimens. The dimensions of the specimens were 7 mm in diameter and 2 mm in thickness. Each capsule of the GICs was activated and placed in a rotating mixer (RotoMix™, 3 M ESPE, Seefeld, Germany) for the recommended time (10 s). The mixed capsule was then loaded into a gun and immediately the cement was injected into a mold. Prior to

material's placement, a polyester strip was placed on a glass slab, the mold was then placed and the material packed. After filling the mold with the cement, a second polyester strip was placed on top of the mold and a second glass microscope slide was clamped to produce a standardized surface finishing and to remove the excess of the material. After 5 min the specimen was removed from the mold and the excess material that extruded around the edge of the mold was carefully removed by using a surgical blade. The surface of each specimen was observed by means of an optical microscope (magnification $\times 10$) to ensure that there were no air bubbles or cracks. The top surface of each glass ionomer specimen was 38.465 mm^2 . The other surfaces of the specimens were covered with an insoluble in water nail varnish.

2.3. Experimental groups

There were three experimental groups ($n = 10$) for each GIC in this study. In Group 1, which was the control group of the study, the specimens after mixing were left in the mold to set without any treatment. In Group 2, after placement in the mold the specimens were irradiated for 60 s at the top surface using a LED light-curing unit (Elipar™ DeepCure-S, 3 M ESPE, St. Paul, MN, USA) at 1470 mW/cm^2 with standard curing mode and wavelength range 430–480 nm (fluence $\sim 1.47\text{ J/cm}^2$). A radiometer (Demetron LED Radiometer, Kerr Corp.) was used to verify the output irradiance of the LED unit. The diameter of the light tip was 10 mm and was in contact with the polyester strip of the top surface of the specimen during irradiation. In Group 3, after placement in the mold the specimens were irradiated for 60 s at the top surface using a blue light diode laser system (SIROLaser Blue, Sirona Dental Systems GmbH, Bensheim, Germany), which emits in continuous wave mode. The wavelength of the laser was $445 \pm 5\text{ nm}$ with an absorbance coefficient of around 10^4 cm^{-1} . MultiTip (lot: 0716), which was used for this treatment with a diameter of 8 mm, was in contact with the top surface of the specimens during irradiation and the average output power of the laser device was adjusted to 0.7 W (fluence $\sim 1.4\text{ J/cm}^2$). All the measurements of the experiments were carried out by two different researchers who did not know which experimental group was tested.

2.4. Evaluation of water sorption and solubility

Evaluation of water sorption and solubility of the tested materials was performed according to ISO 4049:2009. After preparation each specimen was weighed using a calibrated electronic analytical balance (Sartorius TE124 S, Goettingen, Germany) with accuracy up to 0.01 mg. This initial mass of the specimens was referred as m_1 . In addition, the thickness and the diameter of each specimen were measured with a digital caliper (Powerfix® Electronic Digital Caliper, Model: Z22855, Paget Trading Ltd, London, UK) with accuracy up to 0.01 mm. The volume of each specimen was calculated using the following equation: $V = \pi \times r^2 \times h$, where V is the volume, $\pi = 3.14$, r is the radius, and h is the thickness of the specimen. Subsequently, the specimens were immersed individually in 10 ml of deionized water in plastic containers and

Table 1
The technical characteristics of the tested glass ionomer cements.

Material	Category	Manufacturer	Composition	Lot number
Riva Self Cure	Conventional GIC (capsules)	SDI Limited, Victoria, Australia	Powder: Fluoro-aluminosilicate glass 90–95 wt% Liquid: Acrylic acid homopolymer 20–30 wt%, tartaric acid 10–15 wt%	C57371
Ketac Universal Aplicap	Conventional GIC (capsules)	3 M ESPE, Seefeld, Germany	Powder: Oxide glass Liquid: Water, copolymer of acrylic acid-maleic acid, tartaric acid	598170
Equia Fil	Conventional GIC (capsules)	GC Dental, Tokyo, Japan	Powder: Fluoro-alumino-silicate glass 70–80 wt% Liquid: Polyacrylic acid 10–15 wt%, distilled water 10–15 wt%	1505141

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