



ELSEVIER

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.intl.elsevierhealth.com/journals/dema

Examining exposure reciprocity in a resin based composite using high irradiance levels and real-time degree of conversion values

Daniela Selig^{a,b,c}, Thomas Haenel^{a,b,d,e}, Berenika Hausnerová^{d,e},
Bernhard Moeginger^b, Daniel Labrief^f, Braden Sullivan^a,
Richard B.T. Price^{a,*}

^a Dalhousie University, Department of Dental Clinical Sciences, Faculty of Dentistry, Halifax, Canada

^b Bonn-Rhein-Sieg University of Applied Sciences, Department of Natural Sciences, Rheinbach, Germany

^c FH Aachen University of Applied Sciences, Department of Natural Sciences, Jülich, Germany

^d Tomas Bata University in Zlin, Faculty of Technology, Department of Production Engineering, Zlin, Czech Republic

^e Tomas Bata University in Zlin, University Institute, Centre of Polymer Systems, Zlin, Czech Republic

^f Dalhousie University, Department of Physics and Atmospheric Sciences, Halifax, Canada

ARTICLE INFO

Article history:

Received 23 December 2013

Received in revised form

10 December 2014

Accepted 16 February 2015

Keywords:

Mid FTIR

Degree of conversion

Polymerization kinetics

Irradiance

Flowable composite

Radiant exposure

Exposure reciprocity

Dental curing light

ABSTRACT

Objective. Exposure reciprocity suggests that, as long as the same radiant exposure is delivered, different combinations of irradiance and exposure time will achieve the same degree of resin polymerization. This study examined the validity of exposure reciprocity using real time degree of conversion results from one commercial flowable dental resin. Additionally a new fitting function to describe the polymerization kinetics is proposed.

Methods. A Plasma Arc Light Curing Unit (LCU) was used to deliver 0.75, 1.2, 1.5, 3.7 or 7.5 W/cm² to 2 mm thick samples of Tetric EvoFlow (Ivoclar Vivadent). The irradiances and radiant exposures received by the resin were determined using an integrating sphere connected to a fiber-optic spectrometer. The degree of conversion (DC) was recorded at a rate of 8.5 measurements a second at the bottom of the resin using attenuated total reflectance Fourier Transform mid-infrared spectroscopy (FT-MIR). Five specimens were exposed at each irradiance level. The DC reached after 170 s and after 5, 10 and 15 J/cm² had been delivered was compared using analysis of variance and Fisher's PLSD post hoc multiple comparison tests ($\alpha = 0.05$).

Results. The same DC values were not reached after the same radiant exposures of 5, 10 and 15 J/cm² had been delivered at an irradiance of 3.7 and 7.5 W/cm². Thus exposure reciprocity was not supported for Tetric EvoFlow ($p < 0.05$).

Significance. For Tetric EvoFlow, there was no significant difference in the DC when 5, 10 and 15 J/cm² were delivered at irradiance levels of 0.75, 1.2 and 1.5 W/cm². The optimum combination of irradiance and exposure time for this commercial dental resin may be close to 1.5 W/cm² for 12 s.

© 2015 Academy of Dental Materials. Published by Elsevier Ltd. All rights reserved.

* Corresponding author at: Dalhousie University, Dental Clinical Sciences, 5981 University Avenue, Halifax, NS B3H 4R2, Canada.

Tel.: +1 902 494 1226; fax: +1 902 494 1662.

E-mail address: rbprice@dal.ca (R.B.T. Price).

<http://dx.doi.org/10.1016/j.dental.2015.02.010>

0109-5641/© 2015 Academy of Dental Materials. Published by Elsevier Ltd. All rights reserved.

1. Introduction

Photo-polymerizable resin-based composites (RBCs) have become the material of choice for direct restorations [1]. The radiant exposure (RE), namely the product of irradiance and exposure time, is an important factor that determines the degree of conversion (DC) and mechanical properties of photo-polymerizable RBCs [2–7]. The RE required to adequately polymerize a 1–2 mm thick increment of RBC is considered to be between 18 and 24 J/cm². This is based on studies using quartz-tungsten-halogen (QTH) light-curing units (LCUs), which found that it was necessary to deliver a minimum irradiance of 300–400 mW/cm² for 60 s [8,9]. To obviate the need to spend 30 to 60 seconds light curing light curing each increment of RBC, high power curing lights have been introduced to reduce light exposure times and thus shorten chairside procedures. Several authors have investigated what they have described as the ‘Exposure Reciprocity Law’ [10–12], which proposes that there exists reciprocity between irradiance and exposure time to achieve equivalent polymerization of RBCs. Consequently, some contemporary LCUs now deliver irradiance levels up to 6 W/cm², which, their manufacturers’ claim, can allow for very short exposure times (1–3 s) to be used [13,14]. This makes these high output LCUs attractive to dentists who wish reduce the time they spend light curing. It is possible many resins appear to follow exposure reciprocity simply because they have been cured to a high DC [12], but this does not necessarily mean that their physical properties will be the same. Depending on the rate of cure, it has been reported that some RBCs may have different physical properties even when a similar DC is achieved [12]. It has been reported that curing a resin at a higher irradiance with a shorter exposure time can increase the shrinkage stress [15]. It also results in a lower degree of cure, lower flexural strength and lower modulus than curing with a lower irradiance for a longer time [2].

It has been reported that the greater the viscosity of the RBC, the more likely it is to exhibit exposure reciprocity compared to its flowable counterpart [11]. In the very early phase of polymerization the RBC has yet to develop a polymeric network to effectively trap the radicals [12]. Thus during this phase the principle of exposure reciprocity is likely violated. Near the end of polymerization, the principle should hold because almost all of the radicals are now trapped in the glassy network. For each resin system, there appears to be an optimum rate of initiation that produces the highest quantum yield. If the initiation rate is too high, more of the generated free radicals are prematurely spent via bimolecular termination because the medium has yet to develop a polymeric network to trap these free radicals effectively. Conversely, if the initiation rate is too low, many photons may be wasted if the network has already been well established, as this network will trap and annihilate the primary radicals, preventing them from producing polymers [12,16]. When the resin receives a high irradiance, the reaction rates between production and destruction of intermediate molecular species may not be in balance, and steady-state assumptions may not hold [17].

In some cases the irradiance and exposure time can influence the polymer chain length, extent of cross-linking, and

mechanical properties of the resin [2,10–12,18–22]. At high irradiance levels only short polymer chain lengths can be achieved before cross-linking occurs [18,19]. Hadis et al. [11] examined 10 RBCs and reported that a reciprocal relationship between irradiance and the exposure time was observed for five commercial paste RBCs, but only for three out of the five flowable products. They delivered a RE of 18 J/cm² to verify the applicability of the exposure reciprocity concept using irradiance values between 400 and 3000 mW/cm². Using a Fourier Transform near-infrared spectrometer (FT-NIR) in the transmission mode, the time dependent DC and rates of polymerization R_p were measured through 1.4 mm thick RBC specimens. Two of the flowable resins exhibited a lower degree of conversion when exposed to 3000 mW/cm² for 6 s, compared to 400 mW/cm² for 45 s. Using differential scanning calorimetry, Feng et al. [12] reported that for experimental resins with an oligomer/monomer mass ratio equal to or greater than 6:4, the degree of double bond conversion followed a reciprocal arrangement when low irradiance levels between 3.1 mW/cm² and 50 mW/cm² were delivered to the resins. Since most commercial dental resins are similar binary systems, containing mostly viscous oligomers, they concluded that the ‘exposure reciprocity law’ might also apply to dental RBCs.

The available evidence for exposure reciprocity at any irradiance level is contradictory, most likely because different research groups have used different resins, ranges of irradiance and radiant exposures to investigate this phenomenon [2,10–12,23]. One study used very low irradiance levels (3–24 mW/cm²) to investigate the relationship between the radiant exposure and the DC [23]. Using a kinetic model, the authors reported that the polymerization kinetics should not be expected to follow the reciprocity law behavior. At these low levels, as the irradiance increased, the overall radiant exposure required to achieve full conversion also increased. The ultimate conversion did not only depend on the radiant exposure, but also on the irradiation intensity and corresponding polymerization rate [23]. Another study using irradiance levels between 50 and 1000 mW/cm² described a parabolic relationship between irradiance and both flexural strength and flexural modulus [2] for Tetric Ceram (Ivoclar-Vivadent, Schaan, Liechtenstein). For this RBC, the maximum flexural strength and flexural modulus occurred at an intermediate irradiance level. This relationship may be applicable to other resins [12,16]. Other reports examining the concept of exposure reciprocity have based their conclusions on properties such as the elastic modulus [5], the micro-hardness [7], or the depth of cure [10] of the resin measured at a fixed time point after light exposure that ranged from 180 s to 1 week.

Fourier Transform mid-infrared spectroscopy (FT-MIR) is often used to measure the DC of dental resins by assessing the change in ratio of characteristic absorbance peaks of the cured and uncured resin. Commonly the methacrylate aliphatic C–C double bond peak height or area at 1638 cm⁻¹ is compared to the aromatic C–C double bond peak height or area at 1608 cm⁻¹. Additionally, although not commonly carried out, it is recommended that the equipment response be determined using different mixtures of known molar ratios of aliphatic to aromatic groups [24]. Depending on the irradiance level, most of the polymerization reaction occurs within the first 5 s of light exposure [23,25,26]. Previous studies have

Download English Version:

<https://daneshyari.com/en/article/1420684>

Download Persian Version:

<https://daneshyari.com/article/1420684>

[Daneshyari.com](https://daneshyari.com)