DENTAL-3052; No. of Pages 10
ARTICLE IN PRESS
dental materials xxx (2017) xxx–xxx
Available online at www.sciencedirect.com
ScienceDirect
journal homepage: www.intl.elsevierhealth.com/journals/dema

Light irradiance through novel CAD–CAM block materials and degree of conversion of composite cements

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ARTICLE INFO

Article history:
Received 14 June 2017
Received in revised form
20 October 2017
Accepted 9 November 2017
Available online xxx

Keywords:
CAD–CAM
Degree of conversion
Micro-Raman
Light spectrometer
STEM
Composite cement

ABSTRACT

Objective. To assess light irradiance (LI) delivered by two light-curing units (LCU's) and to measure the degree of conversion (DC) of three composite cements, when cured through different thicknesses of two novel CAD–CAM block materials.

Methods. 100-μm-thick films of a dual-curable composite cement (G-CEM LinkAce, GC), a light-curable flowable resin-based composite (RBC) (G-ænial Universal Flo, GC) and a micro-hybrid RBC (G-ænial Posterior, GC) were investigated as luting agents. Two 'polymer–ceramic' CAD–CAM blocks (Cerasmart, GC; Enamic, Vita Zahnfabrik) were sectioned in slabs with different thicknesses (1, 3 and 5 mm). LI at the bottom of the specimens was measured using a calibrated spectrometer, while being light-cured through the CAD–CAM block slabs for 40 s with a low- (±500 mW/cm^2) or high- (±1,600 mW/cm^2) irradiance LCU (n = 5). After light-curing, micro-Raman spectra of the composite films were acquired to determine DC at 5 min, 10 min, 1 h and 24 h. LI data were statistically analyzed by Kruskal–Wallis followed by post-hoc comparisons, while a linear mixed-effect model was applied for the DC analysis. In addition, the CAD–CAM blocks ultrastructure was characterized upon argon-ion slicing using scanning transmission electron microscopy (STEM). Finally, light transmission (LT) through each CAD–CAM block material was assessed using a spectrophotometer.

Results. Curing-light attenuation and DC were significantly influenced by thickness and type of the overlying material. LCU only had a significant effect on DC of the micro-hybrid RBC. DC significantly increased over time for all composite cements. CAD–CAM block structural analysis revealed a relatively small and homogenous filler configuration (mean filler size of 0.2–0.5 μm) for Cerasmart, while Enamic contained ceramic grains varying in shape and size (1–10 μm), which were interconnected by the polymer-based network. LT was much higher at a wavelength range of 300–800 nm for Cerasmart than for Enamic.

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https://doi.org/10.1016/j.dental.2017.11.008

Please cite this article in press as: Lise DP, et al. Light irradiance through novel CAD–CAM block materials and degree of conversion of composite cements. Dent Mater (2017), https://doi.org/10.1016/j.dental.2017.11.008

Significance. Light-curable composite cements can be cured through a restoration up to 2.7-mm thickness, depending on the kind of CAD–CAM material. A high-irradiance LCU only has a limited effect on the maximum thickness of the polymer–ceramic CAD–CAM material that can be cured through.

1. Introduction

Considering that retaining good marginal integrity of an indirect restoration largely determines the restoration's longevity, reduced marginal leakage is the major advantage of an adhesive luting protocol using composite cements over conventional cementation using glass-ionomer or phosphate cements that may additionally present low flexural and compressive strengths [1]. Adequate adhesion can be achieved when applying well-established surface treatments at both the tooth and restoration side. Furthermore, a proper cure of the cement is essential in order to obtain good mechanical properties and avoid cement ditching. Marginal defects are associated with a higher risk on secondary caries and endodontic/periodontal complications [2]. The degree of conversion (DC) of composite cements directly contributes to its mechanical properties and has even been used as a parameter for predicting the clinical performance of restorations [3,4].

Different from the traditional self-curable composite cements (which involve a pure chemical initiation of the polymerization reaction), most of the currently available composite cements are dual-curable (chemically and photo-activated, available in a two-component syringe) or solely light-curable (one-component syringe). The lack of chemical initiators in the exclusively light-curable composite cements makes their polymerization totally dependent on the amount of energy of light transmitted through the restorative material [5]. This category of composite cements is indicated when luting relatively thin and translucent restorations that allow enough light irradiance (LI) to activate the photo-initiators (e.g. camphorquinone) and initiate the chain-polymerization reaction. Recently, there is an increasing trend in the clinic to use flowable and regular consistency restorative resin-based composites (RBCs) as solely light-curable cements for adhesive luting [6,7]. Their 'on command' setting offers clinicians more time to seat the indirect restoration and to remove cement excess, especially in case of difficult accessible subgingival margins [8]. Restorative RBCs also have a stiffer consistency, facilitating excess removal, while some heating is sometimes recommended to reach a better flow during restoration seating. In addition, restorative RBCs are mechanically stronger than the less filler-loaded composite cements and hence can be expected to maintain marginal integrity longer, being less prone to wear and wash-out in particular at stress-bearing occlusal margins [9]. Furthermore, simultaneous cementation of neighboring restorations in one quadrant is possible, since the cement is not chemically cured, which otherwise would force the dentist to remove cement in a restricted time period.

In clinic, diverse tooth-preparation configurations need to be restored; hence, indirect restorations with various thicknesses are required. When light transmittance is compromised due to attenuation in the overlying restoration, DC of the composite cement may be suboptimal, having also a negative effect on the mechanical properties of the cement and its bond strength to both the restoration and tooth substrate [3,10]. Moreover, unreacted monomers (not bonded to the polymeric chain) may be released, thereby potentially irritate the pulp by generating local inflammatory responses [5]. In areas hardly reachable by light, dual-curable composite cements are commonly indicated in order to achieve proper polymerization thanks to the additional chemical polymerization-initiation system. However, it has been shown that light-curing is essential even for dual-curable RBCs in order to reach sufficient material properties [11]. Light attenuation is dependent on the filler-volume fraction, the particle size and shape, and the refractive indices of the composing materials [12]. Moreover, translucency differs depending on the light wavelength and the transmitted spectrum that changes continuously with depth [12,13]. As a result, different combinations of the light-curing unit (LCU) employed and the photo-initiator(s) present in the light-curable material might result in variations in DC. Due to the complexity of all these parameters involved and because of the wide variety that exists in LCUs, CAD–CAM materials and composite cements, it would be rather complex, if not impossible, to measure the independent effect of all these factors. Instead, direct measurement of their overall effect is far more practical and clinically relevant than evaluating all these influencing variables separately. This also means that attenuation is specific for each restorative material and that the maximum thickness through which a material can be light-cured has to be determined for the actual material and LCU.

New types of 'hybrid' CAD–CAM blocks, containing both a polymeric and ceramic phase, have recently been introduced for indirect restorations (fixed partial prostheses, veneers, tooth- or implant-crowns) [14]. However, it is still uncertain whether light-curable and/or dual-curable composite cements can be properly cured through these 'polymer–ceramic' materials, while their thickness and different composition are important factors if adhesive luting is intended. To date, scarce data are available with regard to the potential to light-cure composite cements through novel CAD–CAM block materials [15]. Therefore, this study aimed (1) to evaluate the effect of different CAD–CAM block thicknesses on LI and (2) to measure DC of one dual-curable composite cement and two light-curable RBCs that were used as cements. The null hypotheses tested were (1) that LI delivered and (2) that DC of the composite cements were not affected by (a) the LCU, (b) the thickness and (c) the type of CAD–CAM block material.

Please cite this article in press as: Lise DP, et al. Light irradiance through novel CAD–CAM block materials and degree of conversion of composite cements. Dent Mater (2017), https://doi.org/10.1016/j.dental.2017.11.008