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Effect of short LED lamp exposure on wear resistance, residual monomer and degree of conversion for Filtek Z250 and Tetric EvoCeram composites

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ABSTRACT

Objectives. The latest LED dental curing devices claim sufficient curing of restorative materials with short curing times. This study evaluates mechanical and chemical properties as a function of curing time of two commercial composite filling materials cured with three different LED lamps.
Methods. The composites were Filtek Z250 (3M ESPE) and Tetric EvoCeram (Ivoclar Vivadent) and the LED curing devices were bluephase 16i (Ivoclar Vivadent), L.E.Demetron II (Kerr) and Mini L.E.D. (Satelec). Control samples were cured with a QTH-lamp (VCL 400, Kerr). The wear resistance after simulated tooth brushing, degree of conversion, curing depth, and amounts of residual monomers were measured after different curing times.
Results. The results of this study show that short curing time with high-intensity LEDs may influence the bulk properties of the materials, resulting in lower curing depth and increased residual monomer content. The measured surface properties of the materials, degree of conversion and wear resistance, were not affected by short curing times to the same extent.
Significance. This study demonstrates that reduced exposure time with high intensity LEDs can result in composite restorations with inferior curing depth and increased leaching of monomers. Dentists are recommended to use sufficient curing times even with high intensity LEDs to ensure adequate curing and minimize the risk of monomer leaching.

1. Introduction

As esthetic dentistry has become the ideal, and as the use of amalgam still is debated, restricted or even prohibited in some countries [1–5], composite materials now play a dominating role in modern restorative therapy [6–8]. The longevity and safe use of these materials are influenced by both mechanical and chemical properties, as well as the dentists' technique and experience [7].

The restorative composites are mainly cured using a suitable curing device with visible (VIS), or sometimes ultraviolet (UV) and VIS radiation. Previously, quartz–tungsten–halogen (QTH) lamps were commonly used, whereas through the past

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decade or so, there has been a steady increase in the use of light emitting diode (LED) lamps. Advances in LED technology provide more efficient light emitters with higher energy output. This has led to a claim by some lamp manufacturers that very short curing times are sufficient in order to thoroughly cure a composite restoration. While the recommended curing time for light curing composites previously was approximately 40 s, it is now advertised that the new LED lamps yield acceptable curing after only 5 s. It is recognized that shorter curing times will negatively affect material properties, but few studies have evaluated curing times below 10 s [9–11].

A sufficient amount of light (energy) is necessary in order to achieve a thorough curing extending well into the depth of the material [9,12,13]. It is known that poor curing provides reduced quality of composite materials. Several studies have measured the curing depth or degree of conversion, combined with other properties such as hardness or flexural strength [9,13–16] or residual monomer [17]. However, there is limited documentation on the effect of reduced curing time on the composites' wear resistance, degree of curing, and residual monomer content; to the authors' knowledge, there is currently no study evaluating these properties simultaneously, although they all are important clinical properties. It is unclear what kind of biological impact, if any, a short or reduced curing time could have on the patient, both with respect to excess worn off and leachable material from polymer matrix and filler particles. Clinically, increased attrition of composite filling materials would result in faster replacement due to occlusal wear and loss of contact point.

The aim of this project was to evaluate mechanical and chemical properties as a function of curing time of two commercial composite filling materials, Filtek Z250 (3M ESPE) and Tetric EvoCeram (Ivoclar Vivadent), cured with three different LED lamps. The wear resistance, degree of conversion, curing depth and residual monomer levels were evaluated.

2. Materials and methods

2.1. Materials

Two resin-based light-curing composite restorative materials of shade A3 were included in the study: Filtek Z250 ("Z250", Batch No. 20060919 and N248789, 3M ESPE, St. Paul, MN, USA) and Tetric EvoCeram ("TEC", Batch No. J25696 and N78433, Ivoclar Vivadent, Schaan, Liechtenstein). The composition of the materials is shown in Table 1 based on information provided from the manufacturers in material safety data sheets (MSDS) and instructions for use (IFU).

The study includes three LED curing devices, all emitting blue light at the required wavelength for curing the materials (468 nm): bluephase 16i ("BP", Ivoclar Vivadent), L.E.Demetron II ("DII", Kerr, Orange, CA, USA) and Mini L.E.D. ("Mini", Satelec, Merignac, France). A curing device with halogen bulb was used as control: VCL 400 ("VCL", Kerr). The LEDs were equipped with a narrow light emitter tip for a high power output according to the manufacturer information, see Table 2. The light emitting tip of the QTH-lamp was straight. Two curing times were used for the experiments. A "short" curing time was selected on the basis of the lamp-manufacturer's recommendations on minimum curing time. This time was either 5 or 10 s depending on the curing device and the material. A "long" curing time was selected in accordance with the recommendations from the manufacturers of the composites. IFUs for Z250 described 20 s curing time with a curing device with high intensity. IFUs for TEC recommended 20 s for devices with intensity greater than 500 mW/cm^2 and 10 s for lamps with intensity higher than 1100 mW/cm^2. The "long" curing time was chosen to be 20 s in all cases (Table 2).

2.2. Residual monomer and curing depth

Residual monomer analysis was performed by high performance liquid chromatography (HPLC) (Agilent 1100 Series LC with Zorbax Eclipse XDB-C8 column, Agilent Technologies, Santa Clara, CA, USA) with two detectors: ultraviolet spectrometry (UV-DAD) and mass spectrometry (MS Ion Trap, both from Agilent Technologies). Identification of the peaks of the chromatograms was done by comparing mass spectrum or UV-absorption and retention time of the components with the corresponding reference compounds. ISO 20795-1: 2008 *Dentistry – Base polymers – Part 1: Denture base polymers* [18] was used as a guideline: cured material was placed in acetone for 7 d at room temperature before identification and quantification of the residual monomers in the solution. The amount of residual monomer is presented as weight percentage of the organic matrix (resin). The total filler content (wt% of inorganic and pre-polymerized organic fillers) was determined for each of the uncured materials, using a gravimetric

Table 1 – Composition of the composite materials as given in the IFUs and MSDSs.

Material (manufacturer)	Organic matrix	Fillers
Filtek Z250 (3M ESPE)	Trietyhlenglycol dimetacrylate (TEGDMA) < 1–5%; Bisphenol-A-glycidylmethacrylate (Bis-GMA) < 1–5%; Bisphenol-A polyethylenglycol dietherdimethacrylate (Bis-EMA) 5–10%; Urethane dimethacrylate (UDMA) 5–10%	Zirconia/silica; 60 vol% inorganic fillers; Particle size 0.01 to 3.5 μm
Tetric EvoCeram (Ivoclar Vivadent)	Dimethacrylates (17–18 wt%); Bisphenol diglycidylmethacrylate (Bis-GMA) 5–10%; Urethane dimethacrylate (UDMA) 5–10%	Barium glass, ytterbium trifluoride, mixed oxide, prepolymer, 82–83 wt% (75–76 wt% or 53–55 vol% inorganic fillers); Particle size of inorganic fillers 40–3000 nm, with mean 550 nm