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Polymerization efficiency and flexural strength of low-stress restorative composites

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ABSTRACT

Objectives. To assess depth of cure (DOC), degree of conversion (DC), and flexural strength (FS) of several resin composites with low-stress behavior.

Methods. SonicFill (Kerr), SureFil® SDR™ (Dentsply), everX Posterior (GC), Kalore (GC), and Filtek Silorane (3M ESPE) were tested. DOC was measured with the Acetone Shake test. DC was assessed with Fourier Transform Infra-Red spectroscopy on top and at the bottom of 4 mm-thick disk-shaped specimens. Bottom to top ratios of DC percentages were calculated. FS was evaluated with the Three-Point Bending test. DOC, DC, and FS data were statistically analyzed.

Results. SureFil® SDR™ and everX Posterior achieved significantly greater DOC than Kalore and Filtek Silorane. Also, SonicFill had significantly greater DOC than Filtek Silorane. Mean top DCs ranged between 71.46% and 52.44%. Kalore and everX Posterior had significantly lower top DCs than the other materials. Mean DC values at 4 mm ranged largely from 57.95% to 6.82%. Kalore and Filtek Silorane had the lowest values of bottom DC and the difference was statistically significant. EverX Posterior and SonicFill recorded significantly higher FSs than the other materials.

Significance. SureFil® SDR™ and everX Posterior exhibited DOC over 4 mm, the maximum thickness recommended for bulk placement, while SonicFill recorded DOC values very close to the 4 mm threshold. SonicFill achieved the highest DC at the irradiated surface, as well as at 4 mm depth. SureFil® SDR™ demonstrated similarly uniform curing through the bulk increment. All the tested composites complied with the requirements of FS established by ISO 4049/2009.

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1. Introduction

Polymerization shrinkage stress of resin-based composites can affect marginal integrity and lead to marginal leakage, debonding, secondary caries, post-operative sensitivity, development of perimarginal white lines [1–6]. Curing stress can also be responsible for cusp deflection in high C-factor direct composite restorations, such as large Class I and mesio-occluso-distal Class II cavities [7]. Since all the mentioned conditions adverse the durability of resin-based restorations, research has constantly aimed at the development of materials with low-stress behavior and recently pursued the introduction of novel composites for 'bulk' application. Owing to innovations in monomer chemistry, filler characteristics or polymerization kinetics, such materials provide low curing shrinkage that may enable the omission of incremental layering, thus easing the restorative procedure and saving chair time [6]. However, for effective bulk-filling of large and deep cavities, other characteristics of the restorative composites are desirable beside low shrinkage. Particularly, optical properties and photoinitiating system should ensure adequate depth of cure to the bulk-applied increment. Several recently marketed 'bulk-fill' materials have been claimed to achieve adequate polymerization through a depth of over 4 mm [8–12].

In order to assess the maximal increment thickness of resin composites, researchers have referred to depth of cure (DOC) measurements recorded according to ISO 4049:2000 and ISO 4049:2009 [13–17]. Polymerization efficiency of resin composites has also been assessed by measuring the degree of conversion (DC) with spectroscopic techniques that infer the amount of remaining double bonds [3,18]. Current literature provides DOC and DC data for several materials for bulk filling [3,15–17,19–22]. However, in most of the published studies DC was not measured at the clinically relevant depth for bulk-fill composites of 4 mm [20,21]. Moreover, DOC was assessed as per ISO 4049 with the 'Scrape test' [15–17], yet the suitability of this method for bulk-fill composites has recently been criticized for providing an overestimation of curing depth in comparison with Vickers hardness profiles [16]. In general, the procedure of scraping off the uncured resin-based material has been considered difficult to standardize [23,24], and the Acetone Shake test, a method involving physical removal of the unreacted monomers, has been preferred by some researchers [24–26].

Another clinically relevant feature of a bulk-fill composite is the ability to function as a 'dentin-replacement' material. Such potential can be estimated in laboratory research through the assessment of mechanical properties. Mechanical properties can be expected to vary quite largely among the available bulk-fill composites, in relation to differences in filler load and characteristics. Some products present flowable consistency to enable self-adaptation to cavity walls [8,11], while other materials have higher filler load [10], or feature short glass fibers for reinforcement [12,15]. Among the macromechanical properties that can be tested in laboratory, flexural strength provides an estimate of the composite resin potential to serve as dentin-replacement in high stress bearing areas.

The present study was conducted to assess DOC with the Acetone Shake test and DC at a clinically relevant depth for several resin composites with low-stress behavior. A further objective of the investigation was to measure the flexural strength (FS) attained by the same materials. The null hypotheses that the materials achieve similarly efficient cure and comparable FS were placed under test.

2. Materials and methods

The following resin composites for bulk-filling of posterior restorations were tested: SonicFill (Kerr, Orange, CA, USA), SureFil® SDR™ (Dentsply, Milford, DE, USA), everX Posterior (GC, Tokyo, Japan). Additionally, the nanohybrid composite Kalore (GC, Tokyo, Japan) and the silorane-based composite Filtek Silorane (3M ESPE, St. Paul, MN, USA), exhibiting low-stress behavior, although not specifically marketed for bulk placement [27,28], were included in the study in order to verify their applicability in this simplified filling technique. The chemical composition of the materials is reported in Table 1.

Table 1 – Chemical composition of the tested materials.

Material	Chemical composition
Filtek Silorane (3M ESPE, St. Paul, MN, USA)	Silorane resin; quartz filler; yttrium fluoride; initiating system: camphorquinone, iodonium salt, electron donor; stabilizers; pigments. Filler load 76 wt%; 55 vol%
Kalore (GC Corp., Tokyo, Japan)	Urethane dimethacrylate, DX-511 co-monomers, dimethacrylate (18 wt%); pre-polymerized filler (20–30 wt%); fluoroaluminosilicate glass (20–33 wt%); strontium/barium glass (20–33 wt%); silicon dioxide nanofiller (1–5 wt%); camphorquinone (<1 wt%), pigment (<1 wt%). Filler load 82 wt%; 69 vol%
SonicFill (Kerr Corp., Orange, CA, USA)	Glass, oxide, chemicals (10–30%); 3-trimethoxysilylpropyl methacrylate (10–30%); silicon dioxide (5–10%); ethoxylated bisphenol-A-dimethacrylate (1–5%); bisphenol-A-bis-(2-hydroxy-3-mehacryloxypropyl) ether (1–5%); triethylene glycol dimethacrylate (1–5%). Filler load 83.5 wt%; 83 vol%
SureFil® SDR™ (Dentsply De Trey, Konstanz, Germany)	SDR™ patented urethane dimethacrylate resin, ethoxylated bisphenol A dimethacrylate, triethylene glycol dimethacrylate, butylated hydroxyl toluene, barium-alumino-fluoro-borosilicate glass, strontium alumino-fluoro-silicate glass, camphorquinone, UV stabilizer, titanium dioxide, iron oxide pigments. Filler load 68 wt%; 44%vol%
everX Posterior (GC, Tokyo, Japan)	Bisphenol A-diglycidyl dimethacrylate, triethylene glycol dimethacrylate (24.4 wt%); polymethyl methacrylate (0.9 wt%); E-glass fibers, barium borosilicate glass filler (74.2 wt%); camphorquinone, 2-dimethylamino ethyl dimethacrylate, hydroquinone (0.5 wt%). Filler load 74.2 wt%; 53.6 vol%