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Viscoelastic properties, creep behavior and degree of conversion of bulk fill composite resins

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ABSTRACT

Objectives. The aim of this study was to investigate the viscoelastic properties and creep behavior of bulk fill composites under different conditions and evaluate their degree of conversion.

Methods. Seven bulk fill composites were examined: everX Posterior (EV), SDR (SD), Sonic-Fill (SF), Tetric EvoCeram Bulk Fill (TE), Venus Bulk Fill (VE), x-tra base (XB) and x-tra fil (XF). Each material was tested at 21 °C, 37 °C and 50 °C under dry and wet conditions by applying a constant torque for static and creep testing and dynamic torsional loading for dynamic testing. Degree of conversion (%DC) was measured on the top and bottom surfaces of composites with ATR-FTIR spectroscopy. Statistical analysis was performed with two-way ANOVA, Bonferroni's post hoc test and Pearson's correlation coefficient.

Results. Shear modulus G ranged from 2.17 GPa (VE) to 8.03 GPa (XF) and flexural modulus E from 6.16 GPa (VE) to 23 GPa (XF) when the materials were tested dry at 21 °C. The increase of temperature and the presence of water lead to a decline of these properties. Flowable materials used as base composites in restorations showed significantly lower values ($p < 0.05$) than non-base composites, while being more prone to creep deformation. %DC ranged from 47.25% (XF) to 66.67% (SD) at the top material surface and 36.06% (XF) to 63.20% (SD) at the bottom.

Significance. Bulk fill composites exhibited significant differences between them with base flowable materials showing in most cases inferior mechanical properties and higher degree of conversion than restorative bulk fill materials.

1. Introduction

The most common method of composite resin placement, considered as standard for large cavities, is the incremental layer technique in which the restorative material is placed in subsequent increments of about 2 mm of thickness. Its purpose is to achieve an optimal degree of conversion and depth of cure by curing thin layers of composite resin with a light curing device that is capable of producing adequate output for

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Table 1 – The bulk fill composites resins used in the study and their composition.

everX Posterior GC Tokyo, Japan (EV)	SDR Dentsply De Trey Konstanz, Germany (SD)	SonicFill Kerr Orange, CA, USA (SF)	Tetric EvoCeram Bulk Fill Ivoclar Vivadent Schaan, Lichtenstein (TE)	Venus Bulk Fill Heraeus Kulzer Hanau, Germany (VE)	x-tra base VOCO Cuxhaven, Germany (XB)	x-tra fil VOCO Cuxhaven, Germany (XF)
Base composite (fiber-reinforced) Monomers: Bis-GMA, TEGDMA Fillers: 74.2% wt., 53.6% vol. E-glass fibers 1–2 mm length, PMMA, Ba–B–Si glass filler	Base flowable composite Monomers: Modified UDMA, TEGDMA, EBPADMA Fillers: 68% wt., 44% vol. Ba–B–Si glass	Restorative composite Monomers: Bis-GMA, TEGDMA, Bis-EMA, SIMA Fillers: 83.5% wt., 66% vol.	Restorative composite Monomers: Bis-GMA, UDMA Fillers: 79–81% wt., 60–61% vol. Ba–Al–Si glass, prepolymer filler (monomer, glass filler and YbF_3), spherical mixed oxide	Base flowable composite Monomers: UDMA, EBPADMA Fillers: 65% wt., 38% vol. Ba–Si glass	Base flowable composite Monomers: Bis-EMA, MMA Fillers: 75% wt., 58% vol. Si glass	Restorative composite Monomers: Bis-GMA, UDMA, TEGDMA Fillers: 86% wt., 70% vol. Ba–B–Al–Si glass

the necessary time period [1]. The use of thoroughly cured consecutive layers is considered to be advantageous compared to single thicker layers as a high degree of conversion may result in improved mechanical and chemical properties, decrease of possible elution of monomers and color stability. Moreover, it is suggested that the incremental layer technique results in lower setting shrinkage stresses as the individual layers contribute to a lower C-factor [2], the number of bonded surfaces to the number of un-bonded surfaces.

However, despite the theoretical advantages of incremental layer, there is no general consensus in literature concerning its benefits, as there have been contradictory reports of increased polymerization stresses after using the incremental technique [3] and cuspal deflection of a larger magnitude than that of bulk filling [4]. This may be attributed to the fact that testing regimens differ due to a lack of standardization and also because the simulation of the resin flow transitions during polymerization is difficult [5].

Recently, new composite resins with the ability to be cured in bulk were introduced. Some of them can be used to fill the cavity from bottom to top, while others are used as base materials, usually flowable dentin replacement composites, requiring a layer of a conventional composite resin of 1.5–2 mm to finish the restoration. The manufacturers claim that these materials can be thoroughly cured, while problems as the implementations of voids between consecutive layers and possible contamination between them are avoided. Moreover, the use of a bulk filling protocol lessens the amount of time required for the clinician to complete the restoration, which is beneficial both for practitioner and patient.

Dental composite resins are polymer materials of time-dependent mechanical properties. The study of their viscoelastic properties is necessary in order to characterize them mechanically and can be useful in defining microstructural aspects like degree of cure, cross-linking and the bonding between the inorganic fillers and the organic matrix [6] creep of conventional. The high loading forces during chewing may result in failure of composite restorations, so viscoelastic properties, like creep-strain, are essential as in clinical situation there is strain recovery during the unloading phases [7]. According to Watts [8], the understanding of both elastic moduli and visco-elasticity is valuable in the appraisal of clinical performance of biomaterials. It is therefore important to examine the viscoelastic and creep behavior of these novel materials [9–12], as they are used in stress-bearing restorations

The aim of this study was to investigate the viscoelastic mechanical properties of various bulk fill composite resins under different testing conditions and also to determine their degree of conversion. The null hypothesis was that there would be no differences among the materials' mechanical properties and degree of conversion and that their properties would not be affected by the different testing conditions.

2. Materials and methods

In the current study seven composite resins were used and are shown in Table 1 along with their composition provided by the manufacturers. Among these materials SD, VE and XB are flowable and EV non-flowable base composites requiring another thin layer of composite on top of them. SF, TE and XF can be used in bulk and are restorative composites that may fill cavities without the need of another composite.

2.1. *Mechanical properties*

The materials were tested under the following conditions:

(i) Dry at 21 °C, after 24 h of storage in room temperature of 21 °C.
(ii) Wet at 21 °C, after 24 h of storage in distilled water at 21 °C.
(iii) Wet at 37 °C, after 24 h of storage in distilled water at 37 °C.
(iv) Wet at 50 °C, after 24 h of storage in distilled water at 50 °C.

The different conditions were chosen in order to first evaluate the materials without any other external influence (21 °C dry), under the presence of water (21 °C wet) and then to investigate the behavior when closer to the conditions in the oral cavity (37 °C wet) and lastly the behavior under an excessive increase of temperature (50 °C wet) that may happen in the mouth for brief time intervals.

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