



Pre-heating of high-viscosity bulk-fill resin composites: Effects on shrinkage force and monomer conversion



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ABSTRACT

Objectives: To investigate the influence of pre-heating of high-viscosity bulk-fill composite materials on their degree of conversion and shrinkage force formation.

Methods: Four bulk-fill composite materials (Tetric EvoCeram Bulk Fill—TECBF, x-tra fil—XF, QuixFil—QF, SonicFill—SF) and one conventional nano-hybrid resin composite (Tetric EvoCeram—TEC) were used. The test materials were either kept at room temperature or pre-heated to 68 °C by means of a commercial heating device, before being photoactivated with a LED curing unit for 20 s at 1170 mW/cm². Shrinkage forces ($n = 5$) of 1.5-mm-thick specimens were recorded in real-time for 15 min inside a temperature-controlled chamber at 25 °C (simulating intraoral temperature after rubber dam application) with a custom-made stress analyzer. Degree of conversion ($n = 5$) was determined at the bottom of equally thick (1.5 mm) specimens using Fourier transform infrared spectroscopy. Data were analyzed with Student's *t*-test, ANOVA and Tukey's HSD post-hoc test ($\alpha = 0.05$).

Results: Composite pre-heating significantly increased the degree of conversion of TECBF, but had no effect on monomer conversion of the other materials investigated. For each of the test materials, pre-heated composite generated significantly lower shrinkage forces than room-temperature composite. At both temperature levels, TECBF created the significantly highest shrinkage forces, and QF caused significantly higher shrinkage forces than both XF and TEC.

Conclusions: Both the composite material and the pre-cure temperature affect shrinkage force formation. Pre-heating of bulk-fill and conventional restorative composites prior to photoactivation decreases polymerization-induced shrinkage forces without compromising the degree of conversion.

Clinical significance: Composite pre-heating significantly reduces shrinkage force formation of high-viscosity bulk-fill and conventional resin composites, while maintaining or increasing the degree of monomer conversion, dependent upon the specific composite material used.

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1. Introduction

Increasing the temperature of uncured restorative resin composites has gained popularity among dental practitioners as a way to improve material handling characteristics during placement in a cavity preparation. Pre-heating composites prior to photoactivation generally decreases their viscosity [1], which has been shown to enhance marginal adaptation [2] and reduce microleakage [3] due to improved wetting of cavity walls. Furthermore, increased polymerization temperature enhances both radical and monomer mobility resulting in higher overall

conversion [4–7], which in turn may promote improved physical and mechanical properties of pre-heated composites, such as higher surface hardness, and enhanced flexural and diametral tensile strength [8,9].

However, the higher double bond conversion of pre-heated composites is also accompanied by increased volumetric shrinkage [10,11], which might lead to greater shrinkage stress development during polymerization. Shrinkage stress in composite restorations is the result of polymerization contraction taking place under confinement, due to bonding to cavity walls, and has been implicated as a causative factor for a series of clinical complications including interfacial debonding, post-operative sensitivity, cuspal deflection, and enamel fracture [12,13]. Yet, shrinkage stress is not only a function of the composite's volumetric shrinkage, and thus of its actual dimensional change during polymer network

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formation, but is also determined by the material's time-dependent visco-elastic behavior, characterized by its flow capacity in the early stages of the curing reaction and by the elastic modulus acquired during polymerization [14,15]. Therefore, theoretically, the use of pre-heated composite may not increase polymerization-induced shrinkage forces, if the reduction in viscosity due to heating would allow for increased viscous flow and polymer chain relaxation, and thus increased stress relief compared to room-temperature composite, compensating the effect of the higher volume contraction. However, experimental data on the impact of composite pre-heating on shrinkage stress development is scarce. A previous study revealed higher stress values at increased composite temperatures, but only tested one single brand of composite material [16]. Since reaction kinetics and factors such as thermal conductivity and specific heat capacity differ depending on material composition [17,18], the effect of pre-heating on shrinkage force formation might vary between different composite materials.

Recently, a new category of resin-based composite materials, so-called 'bulk-fill' resin composites, has been introduced to the market in an attempt to simplify and expedite the restoration process. According to the manufacturers, these materials can be adequately photopolymerized in thick layers up to 4 or even 5 mm, which has been confirmed for the majority of bulk-fill composites in studies using infrared spectroscopy [13,19,20] and/or micro-hardness depth profiles [19–21], and been attributed to increased light transmittance of these materials [22]. Owing to differences in rheological properties and application techniques, bulk-fill resin composites are further classified in low-viscosity (flowable) and high-viscosity (sculptable) material types. Pre-heating high-viscosity bulk-fill composites might be an interesting approach to provide a transient viscosity reduction comparable to that of a flowable composite without sacrificing the benefits of superior mechanical properties associated with highly filled resin composites [23]. Any potential gain in material characteristics due to pre-heating should, however, not be achieved at the expense of increased shrinkage stress development. This is especially true for bulk-fill resin composites, given that these materials are generally placed in large volume without incremental layering, resulting in unfavorable configuration factors [12,24]. To date, no information is available in the literature on the effect of increasing pre-cure temperature on shrinkage force formation and double bond conversion of high-viscosity bulk-fill resin composites.

Moreover, studies that have shown optimization in monomer conversion upon pre-heating generally maintained the composite temperature constant during experimentation [4–7]. Clinically, however, heated composite cools rapidly once removed from the pre-heating device and inserted into a tooth preparation [25]. In vivo temperature measurements revealed that when a composite material is pre-heated to 60 °C, the actual composite temperature after placement, at the moment of photoactivation, is reduced to around 36 to 38 °C [26]. Therefore, it is important to evaluate the effect of pre-heating under a non-isothermal condition, where the composite temperature achieved after pre-heating is not stabilized, in order to simulate a clinically realistic scenario.

Based on these considerations, the aim of the present study was to investigate the influence of composite pre-heating on shrinkage force development and monomer conversion of high-viscosity bulk-fill materials and a conventional nano-hybrid resin composite under a clinically relevant non-isothermal condition. The null hypothesis was that pre-heating does not affect polymerization-induced shrinkage forces and double bond conversion of the composite materials.

2. Materials and methods

Four bulk-fill composite materials [Tetric EvoCeram Bulk Fill (Ivoclar Vivadent, Schaan, Liechtenstein), x-tra fil (VOCO, Cuxhaven, Germany), QuixFil (Dentsply DeTrey, Konstanz, Germany), SonicFill (Kerr, Orange, CA, USA)] and one conventional nano-hybrid resin composite [Tetric EvoCeram (Ivoclar Vivadent)] were assessed in this study. Details of the test materials are presented in Table 1. Composite pre-heating was performed using a commercially available heating device (Calset; AdDent, Danbury, CT, USA) preset to 68 °C. A standardized volume of test material (42 mm³) was applied into the center well of the heating device and maintained in place for 5 min with the lightproof device lid on. The 5-min heating time was chosen based on a pilot study which revealed that after 5 min of heating, the resin composite materials attained the preset temperature of the heating device, as measured with a T-type thermocouple (Z2-T-2 M; Labfacility, Hanau, Germany). Room-temperature composite (23 ± 0.5 °C) was used as the control. Photoactivation was performed for 20 s with a LED light-curing unit (Bluephase G2; Ivoclar Vivadent) operated in High-Intensity Mode and equipped with a parallel-walled light guide with a 10-mm diameter light emission window. Output

Table 1
Manufacturers' information about the resin composite materials used in the study.

Material	Composition	Filler size (µm)	Filler content (wt%/vol%)	Shade	Lot no.	Manufacturer
Tetric EvoCeram Bulk Fill	Resin: Bis-GMA, Bis-EMA, UDMA Filler: Barium glass, ytterbium trifluoride, mixed oxide, prepolymer	0.04–3 (mean: 0.55)	81/61	IVA	P73694	Ivoclar Vivadent, Schaan, Liechtenstein
x-tra fil	Resin: Bis-GMA, UDMA, TEGDMA Filler: Barium boron aluminum silicate glass	0.05–10 (mean: 3)	86/70	Universal	1225566	VOCO, Cuxhaven, Germany
QuixFil	Resin: Bis-EMA, UDMA, TEGDMA, TMPTMA Filler: Silanated strontium aluminum sodium fluoride phosphate silicate glass	1–10	86/66	Universal	1109001331	Dentsply DeTrey, Konstanz, Germany
SonicFill	Resin: Bis-GMA, Bis-EMA, TEGDMA Filler: Silanated barium boron aluminum silicate glass, silica	Not indicated	83.5/66	A2	3688724	Kerr, Orange, CA, USA
Tetric EvoCeram	Resin: Bis-GMA, Bis-EMA, UDMA Filler: Barium glass, ytterbium trifluoride, mixed oxide, prepolymer	0.04–3 (mean: 0.55)	76/55	A2	R23586	Ivoclar Vivadent, Schaan, Liechtenstein

Bis-GMA: bisphenol-A-glycidyl dimethacrylate; Bis-EMA: ethoxylated bisphenol-A-dimethacrylate; UDMA: urethane dimethacrylate; TEGDMA: triethylene glycol dimethacrylate; TMPTMA: trimethylolpropane trimethacrylate.

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