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Influence of temperature on volumetric shrinkage and contraction stress of dental composites

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ABSTRACT

Objectives. To test the influence of temperature on contraction stress and volumetric shrinkage of Clearfil AP-X, Venus Diamond, Premise and Filtek Z250.
Methods. Volumetric shrinkage measurements were carried out using mercury dilatometry, while a constraint tensilometer set-up was used for the measurement of contraction stress. Measurements were carried out with a composite temperature of 23, 30, 37, and 44 °C.
Results. Volumetric shrinkage increases with higher temperature. Premise and Venus Diamond show lower volumetric shrinkage than Clearfil AP-X and Filtek Z250. Clearfil AP-X shows the highest contraction stress which slightly increases with higher temperatures. The other composites only show an increase in contraction stress between 23 and 30 °C.
Significance. Heating of dental composites results in a higher volumetric shrinkage. However, the contraction stress does not change significantly due to increased temperature above 30 °C.

1. Introduction

Heating of dental composites prior to placement is often carried out in clinical practice to improve the handling of these materials. Especially when materials are relatively viscous, the preheating will result in a less viscous material with better flow properties [1] which makes placement easier, especially if narrow crevices have to be filled. With the increased flow and adaptation, microleakage may also be reduced [2,3].

Polymerization of a dental resin composite is important in order to obtain material properties that will enhance good clinical performance [4]. On the other hand, polymerization leads to shrinkage strain and contraction stress which might affect the integrity of the bond to dentin [5,6]. Temperature is one of the many factors which can influence the polymerization efficiency of a dental resin composite [7]. The difference between room temperature and the temperature in the oral cavity may lead to a different polymerization rate, degree of cure [8], and therefore different shrinkage properties, due to improved monomer mobility at higher temperatures, allowing more of the polymerization reaction to occur before reaching of the gel-point [9].

It has been reported that the mechanical properties of dental resin composites are considerably higher after curing at temperatures of up to 60 °C [10]. It is well established that preheating will lead to higher monomer conversion [8,9,11–14]. The rapid polymerization at higher temperatures leads to a

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Table 1 – Materials used in this study.

Product	Manufacturer	Color	Batch number	Composition
Clearfil AP-X	Kuraray	A2	1102 A	Bis-GMA, TEGDMA, 70 vol.% fillers (silanated barium glass fillers, silanated silica fillers, silanated colloidal silica), DL-camphorquinone, catalysts, accelerators, pigments, others.
Premise	Kerr	Enamel A2	3543967	Ethoxylated bisphenol-A-dimethacrylate, TEGDMA, 70 vol.% fillers of barium glass (size 0.4 μm) and silica fillers (size 0.02 μm), light cure initiators and stabilizers.
Venus Diamond	Heraeus Kulzer	A2	010038/010036	TCD-di-HEA, UDMA, 63.5–65.1 vol.% fillers of barium aluminum fluoride glass and highly discrete nanoparticles (size 5 nm to 20 μm), rheology modifier, initiator system, stabilizers, pigments.
Filtek Z250	3M ESPE	A2	N256375	Bis-EMA, UDMA, Bis-GMA, TEGDMA, 60 vol.% silane treated ceramic filler (size 0.01–3.5 μm), benzotriazol, EDMAB.

Kuraray Medical Inc., Okoyama, Japan; KerrHawe SA, Boggio, Switzerland; Hereaus Kulzer GmbH, Hanau, Germany; 3M ESPE, Seefeld, Germany. Bis-GMA: bisphenol A diglycidylmethacrylate; TEGDMA: triethylene glycol dimethacrylate; TCD-di-HEA: tricyclodecane-urethane dimethacrylate; UDMA: diurethane dimethacrylate; Bis-EMA: bisphenol A polyethylene glycol diether dimethacrylate; EDMAB: ethyl 4-dimethyl aminobenzoate.

higher degree of cure, but may also lead to elevated stress formation and faster reaching of the gel-point [9]. Although a high degree of cure is very desirable because the higher final double bond conversion will lead to better material properties [4], contraction stress may form a threat to the integrity of the bond to dentin [5,6]. It is known that curing at a higher temperature leads to higher shrinkage of dental composites [15,16] and resin cements [17], although according to some authors this effect is little [18] and not clinically significant [19]. Lohbauer et al. showed a significant effect of preheating on shrinkage after 5 min, but this result was not statistically significant after 24 h [20].

There is, however, very little known about the effect of temperature on contraction stress. Few publications have been published concerning the relationship between contraction stress and temperature. It has been demonstrated that residual stress is increased with increasing temperature [21]. Furthermore, recently published research shows an increase of "shrinkage stress rate" with increasing temperature [22]. This study showed a moderate increase in contraction stress at higher temperatures for most composites, although some materials showed decreased values. More research is needed to fully understand the effects of temperature on contraction stress.

The purpose of this study was therefore to test the influence of temperature on contraction stress and volumetric shrinkage of several commercially available dental resin composites.

2. Materials and methods

Four commercially available resin composites were tested: Clearfil AP-X A2, Premise Enamel A2, Venus Diamond A2, and Filtek Z250 A2 (Table 1).

Volumetric shrinkage measurements were performed with the use of mercury dilatometry as reported by de Gee et al. [23] at 23 ± 0.1 °C and at 30, 37 and 44 ± 0.1 °C. The standard procedure and operation of the dilatometer consisted of: (i) a layer of high vacuum grease (Dow Corning Corporation, Midland, MI, USA) was applied on the flat surface of the glass stopper for separation. (ii) An amount of approximately 300 mg of a resin composite paste was applied on the greased surface of the stopper and flattened to a thickness of approximately 1.5 mm. (iii) After the stopper was inserted into the dilatometer the specimens were light activated with an Elipar Trilight (3M-ESPE, Seefeld, G) for 40 s in standard mode (*ca* 750 mW/cm^2), ensuring complete curing. Recording was started at the moment that the light source was switched on. (iv) After the specimens were removed from the dilatometer, the grease was washed off with ether and the density measured by means of pycnometry with a Mettler AT261 DeltaRange. From each material three specimens ($n = 3$) were measured during a period of 30 min.

Non-compliant contraction stress measurements were performed at 23, 30, 37, and 44 ± 0.1 °C with an Instron 6022 Tensilometer (Instron Ltd., Wycombe, UK) as reported previously [24]. The glass plate (4 mm thick) was sandblasted with Al_2O_3 (50 μm) and remaining Al_2O_3 was removed with compressed air. The surface was treated with Ceramic Primer (3M, St. Paul, MN, USA) and SE Bond (Kuraray Medical Inc., Okoyama, Japan) according to manufacturer's instructions. The bolt head (3.2 mm diameter) was wet-ground on 600 grit SiC sandpaper and then sandblasted with Al_2O_3 (50 μm) and treated with SE Bond and light cured for 20 s. The composite was applied between the glass plate and bolt head, and the cross-head was moved to set the distance between the glass plate and bolt head to 0.8 mm. This configuration resulted in *C*-value of 2 ($C = d/2h = 3.2/1.6$) [25]. The specimens were light cured through the glass plate with an Elipar Trilight (ESPE, Seefeld, Germany) for 40 s in standard mode, ensuring complete curing. From the start of light curing the contraction stress development was measured during 30 min. The stress at 30 min was used for the statistical analysis. The axial contraction of the specimens