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Consistency in the amount of linear polymerization shrinkage in syringe-type composites

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Abstract

Objectives: The purpose of this study was to investigate whether the composite resin in a syringe showed a consistent shrinkage through its content. Additionally, the amount of linear shrinkage was compared between materials.

Methods: Five brands of syringe-type and one brand of carpule-type composite resins were used in this study. To each brand, two to three syringes were assigned. In the carpule-type composite, 15 carpules were used. The linear polymerization shrinkage was measured using a custom-made linometer. In this linometer, the amount of displacement of an aluminum disk, which was caused by the linear shrinkage of composite resin, was recorded by a computer every second for 90 s.

Results: The syringe-type composites showed similar consistencies in the amount of linear shrinkage except one. The linear shrinkage of the carpule-type Tetric Ceram showed more consistency compared with syringe-type composites. The amount of linear polymerization shrinkage varied between materials.

Significance: This investigation demonstrates that the use of carpule-type composites is recommended instead of syringe-types, because of the consistency in its linear shrinkage. The custom-made linometer provides an effective way to study polymerization shrinkage. © 1999 Published by Elsevier Science Ltd. All rights reserved.

Keywords: Composite resin; Polymerization shrinkage; Syringe-type composite; Carpule-type composite; Linometer

1. Introduction

The polymerization shrinkage of a composite resin occurs when the monomer of the composite polymerizes. The polymerization shrinkage of dental composites can be measured by several methods: mercury or water dilatometer [1–3]; the linometer [4] or by measuring the specific gravity differences between uncured and cured composite samples [5]. The use of a linometer has merits such as simple and easy application, and it is unaffected by temperature [4]. It has been reported that there are significant differences in the magnitude of polymerization shrinkage among commercially available composite materials [1–4,6]. In these shrinkage measurement studies, randomly selected composite portions in a syringe were measured four to eight times. This study design is only valid when the entire content of the composite resin syringe shows the same amount of polymerization shrinkage. It has not yet been reported whether all

the composites in a syringe have consistent shrinkage. Braem et al. [7] reported that the composite in a single syringe might be deranged when it was under pressure. As the polymerization shrinkage is influenced by the monomer/polymer ratio, the derangement of the content may influence the amount of polymerization shrinkage. The purpose of this study was to investigate whether the composite resin in a syringe showed consistent shrinkage through its contents. Additionally, the amount of linear polymerization shrinkage was compared between different materials.

2. Materials and methods

Five different brands of syringe-type composite resins and one brand of carpule-type composite resin were used in this study. They are listed in Table 1. All the composites except Aelitefil and Herculite XRV had more than two years remaining before their expiry date. For Aelitefil and Herculite XRV, the expiry date was not known because it was not provided. Thus, we used the composites, which we had recently ordered from the company. For Tetric Ceram,

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Table 1
Composites used in the study

Material	Code	Shade	Lot no.	Expiry date	Manufacturer
Z100	Z1	A2	19970625	2000, June	3M Co., St. Paul, MN, USA
	Z2	A2	19970625		
	Z3	A2	19970625		
Herculite XRV	H1	A2	3604-22875		Kerr Mfg. Co., Romulus, MI, USA
	H2	A2	3604-22875		
	H3	A3	3604-22861		
Prodigy	P1	A2	706949	2000, June	Kerr Mfg. Co., Romulus, MI, USA
	P2	A2	706949		
	P3	A2	706949		
<i>Tetric Ceram</i> Syringe type	T1	A2	913072	2001, June	Vivadent AG, Schann, Liechtenstein
	T2	A2	913072		
	T3	A2	913072		
Carpule type	Tc	A2	912556	2001, July	
Aelitefil	A1	A40	069224		Bisco Inc., Itasca, IL, USA
	A2	A5	029024		

Prodigy, and Z100, composite resins of the same batch number were used. In Herculite XRV, two composites had the same batch and one was different. In Aelitefil, the batch numbers of the composite resins were different. Sixteen carpules of Tetric Ceram, which had the same batch number, were included to be compared with syringe-type Tetric Ceram.

The composites, which were pressed out of each syringe, were transferred to the Teflon mold to ensure the same amount of composite for the linometer. After a slight amount of composite was either added or subtracted in the mold, the composite was transferred to the disk in the custom-made linometer, which had been previously coated with separating glycerine gel (Airblock, De Trey Division,

Dentsply Limited, Weybridge, Surrey, England). The composite resin was then covered with a slide glass and aluminum shield. The surface of the slide glass facing the composite had also been coated with the separating gel. Then, the shield was covered and fastened under constant pressure to the base metal. The position of the disk was adjusted to its zero position with the height adjustment screw (Fig. 1).

The light curing unit (Optilux 500, Demetron/Kerr, CT, USA), the light intensity of which was determined at 990 mW/cm^2 by the installed radiometer, was positioned as close as possible to the aluminum shield surface and fixed into position with screws. The composite was then light cured for 60 s. As the composite under the slide

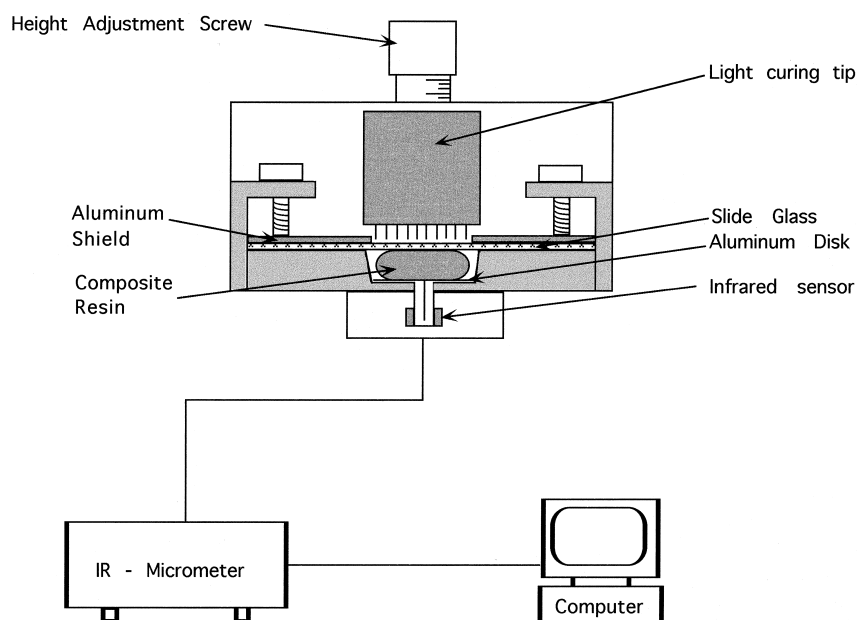


Fig. 1. Schematic drawing of the linometer with a composite sample in place.

Table 2
The position of the composite in each syringe which showed the highest linear shrinkage value (x-axis: composite portions)

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Z1										o					
Z2										o					
Z3						o									
T1			o												
T2														o	
T3														o	
H1														o	
H2									o						
H3					o										
P1					o										
P2										o					
P3					o										
A1											o				
A2	o														

glass cured, it shrunk toward the light source, and the aluminum disk under the composite moved upward. The amount of displacement of the disk, which was caused by the linear shrinkage of composite resin, was measured with a custom made infrared (IR) micrometer. The analog signal was converted to digital data by an A/D converter, then recorded in a computer every second for 90 s using the Excel 5.0 program. These processes were repeated sequentially from the first to the last part of composite resins, which were extruded from the syringe and recorded in the computer. The position of the disk was adjusted to its zero position with the height adjustment screw before every shrinkage measurement. For each syringe, 15 measurements were made. For carpule-type composite resins, 15 carpules of Tetric Ceram were used because only one measurement was possible per carpule. The thickness of the light cured samples was measured up to 1/100 of a millimeter.

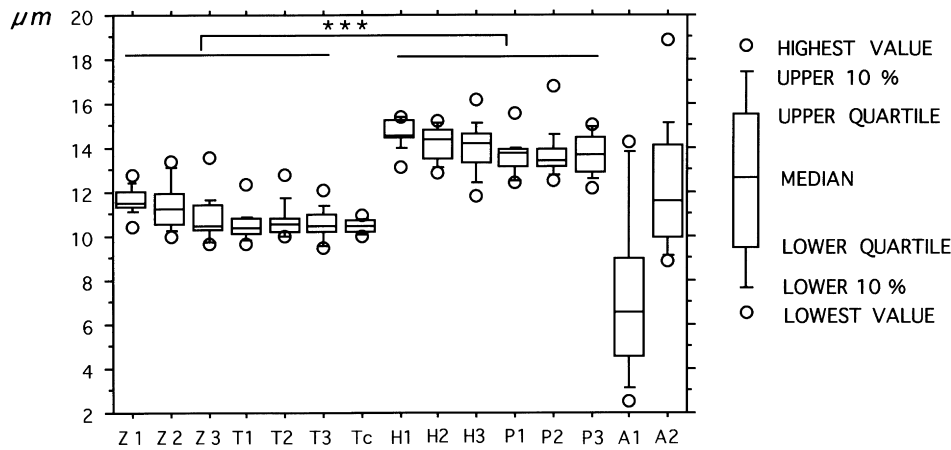
After all measurements were completed, the distribution

of values was plotted with the box plot. Regarding the Tetric Ceram materials, the difference in the variance of the shrinkage values between the three syringe-types was compared with the carpule-type (*F*-test). In order to compare the linear shrinkage value of the different syringe-type composites, an analysis of variance with linear contrast was carried out; for this purpose, the composites were divided into two groups (Z100 and Tetric Ceram vs HerculiteXRV and Prodigy). The position of the composite, which showed the highest shrinkage in each syringe, was evaluated. This was possible because the shrinkage of composite resins was recorded sequentially. To evaluate which part of composite in each syringe showed a higher shrinkage value than other parts, the data of the first three sections per syringe of all the syringes of a material were pooled and averaged. These processes were repeated sequentially from the first to the last data and the results are in five sections per syringe (instead of 15) and nine measurements per section (three measurements per section for each of the three syringes). The data were analyzed by ANOVA.

3. Results

The syringe-type composites showed similar distribution in linear shrinkage values except Aelitefil. The interquartile range (distance between lower quartile and upper quartile) was within 2 μm for syringe-type Z100, Tetric Ceram, Herculite XRV, and Prodigy. In the Aelitefil syringe, the amount of shrinkage varied extremely when compared to the other composite resins (Fig. 2).

The linear polymerization shrinkage was lower for Z100 and Tetric Ceram (first group) than for Herculite and Prodigy (linear contrast *p* < 0.001, second group). Except for Aelitefil, the amount of linear polymerization shrinkage



*** *p* < 0.001

Fig. 2. Amount of linear polymerization shrinkage of syringe- and carpule-type composites.

Table 3
Amount of linear and percentage volumetric polymerization shrinkage

Material	Z100	Tetric Ceram (syringe type)	Tetric Ceram (carpule type)	Herculite	Prodigy
Linear shrinkage (μm)	11.3	10.6	10.5	14.3	13.6
Volume shrinkage (%)	2.03	1.89	1.88	2.53	2.41

was similar among the different syringes of the same brand whether they had the same batch number or not.

The syringe-type Tetric Ceram showed a wider distribution in polymerization shrinkage values than the carpule-type Tetric Ceram (*F* test, $p < 0.01$).

The positions of the composite within a syringe, which showed the highest linear shrinkage varied between brands (Table 2). In Tetric Ceram, the last part of the composite in the syringe showed the highest linear shrinkage in two of three syringes. In Z100 and Prodigy, the highest linear shrinkage usually occurred in the middle third. In Herculite XRV, it occurred irregularly. However, statistical analysis did not reveal that the linear shrinkage value varied within a syringe for all syringe-type composites ($p > 0.05$).

The average thickness of the light cured samples was 1.66 ± 0.01 mm. In Aelitefil, as the amount and distribution of linear shrinkage values were so different from other materials, a statistical comparison with other materials was not made.

4. Discussion

The design of the custom-made linometer (Fig. 1) was basically the same as described by de Gee et al. [4]. The polymerization contraction of the composite displaced the thin aluminum disk and the amount of disk displacement was digitally recorded in the computer. The function of the shield was to make the sample thickness constant by fastening it into the glass under constant pressure. Further, as a 6-mm diameter hole was made in this shield, we could control the amount of light that passed through the shield. The air vent which was included in de Gee et al.'s design was not necessary in this study because the linometer in this study was developed only for the measurement of the linear shrinkage of composite resins.

As the proper greasing of the aluminum disk and cover glass surface is important in measuring the linear shrinkage [4], efforts were made to keep the same separating condition on the aluminum disk and cover glass. Except for this delicate procedure, the custom made linometer proved a simple and effective way to measure polymerization shrinkage.

The linear shrinkage value might be affected if the measuring time extended for hours because separation between the composite and disk would occur with time. This would be one drawback of the linometer.

Even though optimum hardness of the composite resin surface was achieved one day after light curing [8], the prevailing part of the increase in hardness was observed in

the first few minutes after irradiation [9]. In this study, the shrinkage value was recorded for 90 s. In the pilot study, we found that the 90 s shrinkage value mirrored the long-time shrinkage value. As this was a comparative study, it was designed to record the shrinkage value for 90 s.

In this study, the amount of linear shrinkage was directly compared between materials rather than after it was converted to percent linear shrinkage or percent volume shrinkage. This is a more efficient way to show the differences in the amount of shrinkage. This was made possible by accurately controlling the sample thickness by fastening the shield on the glass under constant pressure. When the linear shrinkages are converted to percentage of volumetric shrinkage (Table 3) according to the methods by de Gee et al. [4], they ranged between 1.88% (Tetric Ceram) and 2.53% (Herculite XRV), which is within the range of the previous reports [1–4,6].

In this study, Tetric Ceram and Z100 showed less linear shrinkage than Prodigy and Herculite. According to Ruyter [10], the monomer composition, amounts of diluent monomer, and filler content affect the amount of polymerization shrinkage. According to the manufacturers, the inorganic filler loading by volume is 66% in Z100 and 59% in Prodigy and Herculite XRV. In Tetric Ceram, the weight percent of diluent monomer, TEGDMA, is about 20% of the total monomer. This is a lower value compared to the 30–50% of diluent content reported by Ruyter and Øysæd [11]. High filler loading in Z100 and a lower percentage of diluent monomer in Tetric Ceram may be the reason for the low polymerization shrinkage observed.

The consistency of the linear polymerization shrinkage in the syringe-type composite was relatively high, except Aelitefil. This means that Aelitefil was more inhomogeneous than other materials. In Aelitefil, some parts of the composite seemed to even expand abruptly during the polymerization process, which was probably due to the precured hard particles in the composite. In one syringe of Aelitefil, some part of the composite did not react to the curing light for quite a long period of time. We cannot rule out the possibility that a linometer is not suitable for the shrinkage measurement of Aelitefil. Warping in the composite which is mostly caused by uneven polymerization or precured particles might occur during the linometer measurement. The warping may also be caused by the inhomogeneous composite matrix, in which there may be some portions of precured composites. These phenomena often occur when the composites exist beyond the shelf life. As the expiry date was not printed on the Aelitefil syringes, we do not know if there was a mistake in the manufacturing process or if the

materials were already out of date, though they were purchased recently.

The position of the composite resin, which showed the largest shrinkage value in the syringes varied among materials, even though statistical analysis did not show whether the linear shrinkage value varied within a syringe. In Tetric Ceram, it was at the end in two of three syringes. This may be due to the internal derangement of composite monomers, which occurred in pressing the composite syringe [7]. In Z100, it was in the middle portion. According to Opdam et al. [12], Z100 is categorized as a thin-consistency composite. Thus, less pressure would be needed to extrude material from the syringe and this may cause less chance of derangement of the composite monomer. In Prodigy, the shrinkage was marked in the middle portion of the composite. In Herculite XRV, the former version of Prodigy, the position of the composite resin, which showed the largest shrinkage value in the syringes, varied among syringes. According to Opdam [11], Herculite is categorized as a thick consistency composite. It is assumed that the monomer in Herculite XRV, in which the inhomogeneous monomer may have been included in the manufacturing process, did not undergo derangement because of the thick consistency preventing monomer movement. To understand which part of the composite in a syringe shows a higher shrinkage value than other parts of the composite would be helpful to the clinician because he may be able to prevent clinical problems which is caused by higher polymerization shrinkage. Due to the limited number of samples in this study, further study, which will include more syringe-type composites of the same batch would be desirable for accurately positioning which part of the composite shows higher shrinkage value.

The consistency of linear polymerization shrinkage in the carpule-type composite was higher than in the syringe-type. This means that the composite in the carpules is more homogeneous than the composite in the syringes. It is not yet clear whether this inhomogeneity in the syringe-type is related to the internal derangement of the monomer or if it occurred during the production process. Considering the relative

inconsistency of linear polymerization shrinkage in the syringe-type composite the use of the carpule-type composite in the clinic is recommended.

Acknowledgements

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