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EFFECT OF PREHEATING OF BULK-FILL RESIN DENTAL COMPOSITE ON POLYMERIZATION SHRINKAGE STRAIN

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ABSTRACT

Objectives: This in-vitro study was designed to investigate the effect of preheating two bulk-fill resin composites on the polymerization shrinkage strain.

Materials and Methods: A total of 22 resin-based composite discs were prepared and divided into two equal groups: a thermo-viscous one (VisCalor Bulk) and a high viscosity resin-based composite (X-tra fil). For VisCalor composite resin specimens a VisCalor Dispenser (VOCO, Cuxhaven, Germany) was used for pre-heating of the composite specimens to be injected into a Teflon mold. A Teflon mold with dimensions 7×4×4mm was fabricated to produce the standardized resin composite specimens. The reason for selecting a Teflon frame was to prevent adhering of the resin composite to the frame and so allowing its free shrinkage. A foil electrical resistance strain gauge was used to measure the polymerization shrinkage strain of the resin composite specimens. Analyzing the results was conducted using SPSS version 20, set at Significance level $p \leq 0.05$. Then, data was recorded, tabulated, and statistically analyzed using Kolmogorov-Smirnov and Shapiro-Wilk tests.

Results: X-tra fil group has a significantly higher value (-1130.16 ± 237.56) in comparison to VisCalor group (-616.13 ± 114.75). The difference between the groups was (514.02 ± 12.17) and was statistically significant ($p = 0.000$).

Conclusion: Preheating of VisCalor bulk-fill resin composite to 65˚C has a superior effect to a degree on decreasing the polymerization shrinkage strain than the high viscosity bulk-fill resin composite.

KEYWORDS: VisCalor, Thermo-viscous technology, Preheating, Polymerization shrinkage strain, Bulk-fill

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INTRODUCTION

Composite resin was introduced by **Bowen in 1957** [1]. Since it has been the most widely used dental material, this has resulted in increasing patients' demands for both posterior and anterior cosmetic restorations [2]. Polymerization shrinkage is considered one of the main limitations of resin composite [3]. This polymerization stress passed to the tooth causing clinical manifestations and complications represented by microleakage, debonding, cuspal deflection, microcracking of enamel margins, pulpal irritation, and post-operative sensitivity [4] [5].

The incremental layering technique was introduced as a trial to decrease the polymerization shrinkage stresses; however, it was considered as a technique-sensitive procedure that needs special instruments and requires high clinical skills. As a result, manufacturers realized that more efficient approaches and less sensitive techniques are still needed to decrease resin composite polymerizations shrinkage and so their efforts have resulted in the synthesis of bulk-fill resin-based composites which can be inserted and cured in large increments of 4-5 mm to decrease both operating time and technique sensitivity [6] [7].

Compared to a conventional technique, bulk-fill composites have a higher depth of cure with the sufficient degree of conversion and may result in the reduction of polymerization stress and decreases the voids between layers [8]. However, the high viscosity of bulk-fill composites can contain air bubbles during manipulation and lead to the formulation of internal voids. Also, some studies revealed that high polymerization stresses long cavity walls induced in deep cavities restored with bulk-fill resin composite compared to the multilayer technique [9].

Preheating of the resin composite is a common technique used to reduce the composite viscosity and hence increases the flowability and reduces film thickness which can facilitate the application of composite material and make it less time-consuming [10]. Also, preheating composite resin improves the restoration adaptability to the cavity and reduces shrinkage forces which provides an overall clinical success [11] [12].

Bulk-fill resin composite (VisCalor bulk) designed with thermo-viscous technology with its heating device (VisCalor-dispenser) was found to have the advantage of bulk-fills and preheating [13] [14]. Using infrared technology, this delivery system can heat the composite resin restorative material in seconds and allows their immediate application inside the cavity with the capsule maintained inside/enclosed within the heating device and thereby did not change or reduce the temperature of the composite resin [15] [16] [17].

Aim of the study

This study has been conducted to evaluate the effect of preheating thermo-viscous bulk-fill (VisCalor) resin dental composite and high viscosity resin-based composite (X-tra fil) without heating on the polymerization shrinkage strain. The null hypothesis is that there were no statistically significant differences between the two tested resin composites.

MATERIALS AND METHODS

Ethical approval

This study has been reviewed and approved by Badr University In Cairo BUC Institutional ethical committee with approval number:BUC-IACUC-221130-11

Sample size calculation based on polymerization shrinkage

To evaluate the effect of different resin composites on polymerization shrinkage, an independent t-test or an equivalent non-parametric test is applied for comparison between two groups. Based on **Lotfy et al in 2022** [43], polymerization shrinkage varied from 635±54.77 to 569±51.16.

TABLE (1) Sample size calculation

	Effect size	α error	Power (1-β error)	Total sample size	Sample size per group
Polymerization Shrinkage	1.24	0.05	0.95	22	11

Sample size was determined utilizing statistical power analysis program "G power" (version 3.1.9.4). A sample size of 11 in each group (n=22) is adequate to detect a large effect size (d=1.24), with an actual power (1-β error) of 0.95 (95%) and a significance level (α error) of 0.05 (5%) for the two-sided hypothesis test.

Specimens preparation

Two bulk-fill resin based composites were used in this study, a thermo-viscous one (VisCalor Bulk) and a high viscosity resin-based composite (X-tra fil). VisCalor Dispenser (VOCO, Cuxhaven, Germany) was used for the pre-heating of the composite samples. Twenty two resin composite specimens were prepared and then were divided into two equal groups according to the type of resin composite A Teflon mold was used with dimensions of 7×4×4mm to produce standardized resin composite specimens. The Teflon mold was selected so as not to adhere to the resin-based composite, and so permitting its free shrinkage. For the first group: The VisCalor dispenser was used to load the VisCalor resin composite compule shade A3. The composite resin compule was heated to a temperature of 65°C on mode 1 for a heating time of 30 seconds. After reaching the required temperature the dispenser light flushed indicating that the heating device has stopped, which in turn indicated the start of the packing time (2.5 minutes) according to the manufacturer's instructions. The composite was then injected into the Teflon mold. For group X-tra fil, the bulk-fill X-tra fil composite compule shade A3 was loaded into the cap dispenser (VOCO, Cuxhaven, Germany) without preheating; and the resin composite was then injected into the Teflon mold.

Measurements of polymerization Shrinkage Strain

For measuring the polymerization shrinkage strain, a glass slap worked as a base for the setup. A foil electrical resistance strain gauge (Strain Gauge, Kyowa Electronic Instrument Co, LTD, Tokyo, Japan, Lot #Y5006S) was used to calculate the strain of the resin composite specimens. The length of the gauge was 2 mm in length and had a 120W-electric resistance and a 2.09 ± 1.0%-gauge factor.

The resin-based composite compule was injected into the Teflon mold each time, with the strain gauge centralized in place. Complete filling of the Teflon mold by resin composite was done. A Mylar polyester strip (Foshan, China) was then placed. Pressure application was performed through a second glass slide to remove any excess resin composite. A strain monitoring device (Strain Meter PCD-300A Kyowa-Electronic Instruments Co, LTD, Tokyo, Japan) was connected to the foil-strain gauge

TABLE (2) Material, manufacturers, and composition of bulk-fill resin-based composites

Material	Manufacturer	Shade	Resin System	Filler	Filler Loading
VisCalor Bulk	Voco, Cuxhaven, Germany	A3	Bis-GMA, Aliphatic dimethacrylates	Inorganic nanohybrid filler	83 wt%
X-tra fil	Voco, Cuxhaven, Germany	A3	Bis-GMA, UDMA, TEGDMA	Barium-boron-aluminosilicate glass	86 wt%

and was initially balanced at zero. A light emitting diode curing unit (Densply, Woodbridge, Canada) with an intensity of 1400 mW/cm^2 was used to cure the resin composite at zero-degree distance. Strain measurements were recorded during curing and 10 minutes following light curing for each experimental condition (n=5). PCD30 strain meter software was used to obtain strain versus time curves for different testing conditions.

RESULTS

Statistical Package for Social Sciences (SPSS) version 20 were used for data management and statistical analysis. Numerical data were summarized using mean, standard deviation, and confidence intervals. To determine normality, the Kolmogorov-Smirnov and Shapiro-Wilk tests were used by checking the distribution in the data explored.

Comparisons with respect to normally distributed numeric variables were performed between groups using independent t-test. All p-values were two-sided. Significance level was set at P-values ≤0.05.

The X-tra fil group recorded a significantly higher value -1130.16 ± 237.56 in comparison to VisCalor -616.13 ± 114.75. The difference between the groups was 514.02 ± 12.17. This difference was statistically significant at p = 0.000 (Table 3, Fig.1-2).

TABLE (3) Descriptive statistics of Polymerization shrinkage Strain and comparison between groups (independent t-test)

Groups	Mean	Std. Dev	Difference				T	P
			Mean	Std. error	C.I. lower	C.I. lower		
VisCalor	-616.13	114.75	514.02	79.55	-348.1	-680	6.462	0.0001*
X-tra fil	-1130.16	237.56						

-Significance level p≤0.05, *significant C.I.= 95% Confidence Interval

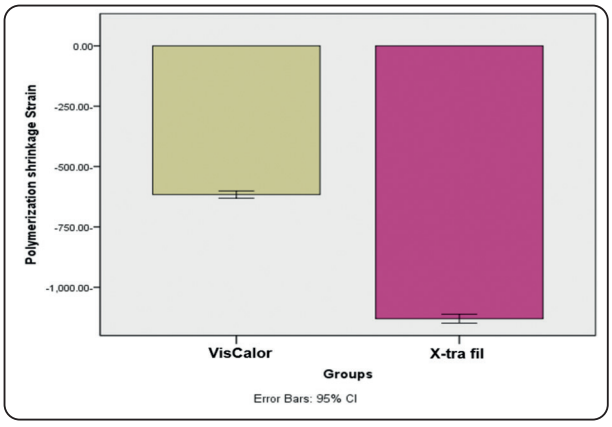

Fig. (1) Bar chart illustrating mean value of polymerization shrinkage strain in the study groups

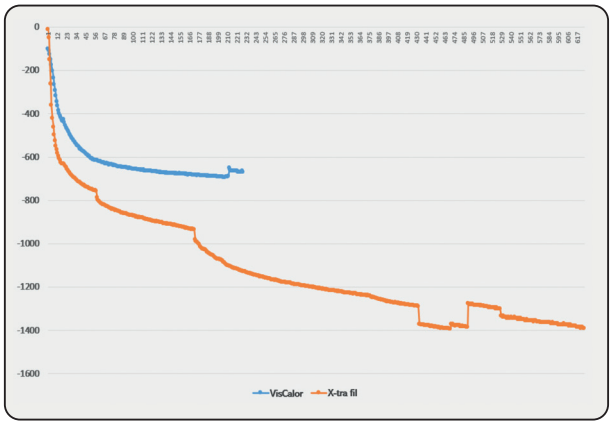

Fig. (2) Line chart illustrating the mean value of polymerization shrinkage strain by time in the study groups

DISCUSSION

This study has been conducted to evaluate the effect of preheating of thermos-viscous (VisCalor) bulk-fill resin dental composite and high viscosity one (X-tra fil) without heating on the polymerization shrinkage strain. A significant difference in the polymerization shrinkage strain of the two tested bulk-fill resin composites were shown in the results. Each type of resin composite has its own insertion technique, emphasizing that the type of the material and insertion technique influence the polymerization shrinkage strain of resin composite restoration. Therefore, the null hypothesis was rejected.

Since their introduction, Bulk-fill resin composites have gained widespread popularity due to their simplifying packing technique [18], decreasing chair side time besides their improved curing properties, reduction of cuspal deflection [19,20], and better control of polymerization shrinkage stresses as this was proved by the meta-analysis and systematic review by **Akah et al in 2017** [21] .

Using of stress-relieving monomers and fillers beside reactive photo-initiators in the Bulk-fill composites permit for modulation of the polymerization reaction. Furthermore, technique sensitivity has been reduced due to filling the cavity in a single layer which in turn reduces void incorporation and any contamination possibility between composite layers entailing to more lasting restorations [21] [22] [23] [24] [25] [26]

One of the main drawbacks of resin composite restorations is the polymerization shrinkage and its sequale manifested by cuspal displacement, cracked cusps, enamel fracture, adhesive failure interface and micro-cracking of the restoration (**Giachetti et al in 2006**) [2, 27, 28, 29].

Several advantages have been gained from preheating resin composites. Some of these are reduced polymerization shrinkage as it was found that increasing temperature reduces the composite resin viscosity and increases the radical mobility and hence improving the adaptation and resulting in a higher degree of conversion (**Baroudi and Mahmoud in 2015**) [30].

A thermo-viscous technology bulk-fill resin composite was introduced allowing the advantage of preheating resin composite before packing which results in the material becoming less viscous, allowing for similar application as that obtained by flowable composite [31, 32]. Therefore, the current study was conducted to investigate the effect of preheating VisCalor thermo-viscous bulk-fill resin composite at 65°C versus X-tra fil bulk-fill resin composite without preheating at room temperature 23 ± 2°C on the polymerization shrinkage strain.

A recently developed and innovated heating device named VisCalor dispenser is considered the perfect device to be used in combination with VisCalor bulk-fill resin composite compules that can not only can be warmed up but can also be applied immediately afterward without the need to change devices. The dispenser application warmed up the material very quickly using near-infrared technology which in turn decreases the viscosity of the material, enhancing its flow on the margins and undercut areas which minimizes the risk of marginal gaps and prevents air bubbles. The device's mode 1 indicates heating to a temperature of 65°C for 30 seconds which considered as pre-warming time then followed by 2.5 minutes as working time [32].

During the application of the nanohybrid composite VisCalor bulk, it was applied while it is still flowable inside prepared cavity and reaches body temperature once comes in contact with the tooth and returns back to its sculptable high viscosity in a short time [33].

Teflon material was used during mold construction so as not to adhere to the resin composite specimens during its insertion, and so allowing and helping in its free shrinkage. A strain monitoring device was used in measurement of the

polymerization shrinkage strain as it was considered a simple and available technique to determine the post-gel shrinkage strain [16].

A limitation of this study is that only one brand of preheated bulk-fill composite resin material was tested and since different types and brands of composite resin have different chemical formulations and hence resulting in different physical and mechanical properties of the resin composite so the results of the present study cannot be extrapolated to other brands of composite resin. Also, testing resin composite material at different temperatures, and investigating the effect of this on its mechanical properties is encouraged for future research. [34].

The results of this study showed that there was a statistical difference between VisCalor group and X-tra fil group resin composites. The mean value of polymerization shrinkage strain of X-tra fil group was significantly higher than that of VisCalor group (-1130.16 ± 237.56 and -616.13 ± 114.75 respectively). The difference between the groups was 514.02 ± 12.17. This difference was statistically significant at $p = 0.000$. The Null hypothesis was rejected because preheating resulted in a statistically significant among the two tested bulk-fill resin composites on polymerization shrinkage strain. The results of this study were in agreement with **Yang et al in 2020** [16] who found that preheating of VisCalor did not increase polymerization shrinkage strain. They attributed this to the fact that during the early stage of polymerization, the preheating of the composite allows for sufficient flow of polymer chains which decreases the internal stress formation within the cavity. Also, the enhanced marginal adaptation from preheating of resin-based composite for the developed shrinkage resulted. Also, preheating enhances the monomer conversion and restrictions the mobility of unreacted monomers to reach the reactive sites which results in decreasing rate of polymerization (**Wang et al in 2019** [35]**, Sirovica et al in 2020** [36]).

Also, these results were in agreement with **Lopes et al in 2020** [37] who found that preheating of resin composite decreases the viscosity, increases the adaptation to the cavity walls and improves many physical properties like higher degree of conversion and lower polymerization shrinkage. They attributed these results to that preheating of resin composite enhances conversion without hastening the time at which the maximum curing rate occurs. This improvement resulted from the increased molecular mobility and collision frequency of the reactive species. Although many studies have shown the benefits of preheating the resin composite, others have shown that there is no improvement in the physical properties of resin composite as polymerization shrinkage, degree of conversion, marginal microleakage, microhardness and flexural strength (**Erhardt et al in 2020** [38]**, Almeida et al in 2018** [39]**, Tantbirojn et al in 2011** [40]). Also, **AbdulMajeed et al in 2020** [34] and **Daronch et al in 2006** [41] showed that composite preheating significantly enhanced (increased) monomer to polymer due to increasing the mobility of monomer and filler particles resulting in enhancement of polymerization.

The results of this study were in disagreement with **Kampanas in 2018** [42] who found higher polymerization shrinkage in preheated resin composites since polymerization shrinkage is directly proportional to the degree of conversion.

These results were in agreement with **Lotfy et al in 2022** [43] who found that VisCalor thermo-viscous bulk-fill composite has a lower polymerizing shrinkage strain values than Admira fusion X-tra and also in agreement with **Deb et al in 2011** [25] where they found that the preheating of dental composites significantly improves the linear polymerization shrinkage and degree of conversion, also with **Lohbaurer et al in 2009** [44] as they found that preheating composite resins didn't significantly increase the polymerization shrinkage strain.

These results were also in disagreement with **ElKorshy in 2010** [45] where preheating of resin composite enhanced its degree of conversion and also increased post-gel shrinkage strain, and this was attributed to three reasons: first preheating resulted in a higher rate of polymerization where a rapid stress built-up was created within the composite resin. Secondly the preheating increases the degree of conversion which results in an increase in the volumetric shrinkage and elastic modulus within the composite. Third, the effect of the main thermal shrinkage of preheated composite as it cools within the material.

CONCLUSIONS

The aim of the introduction of thermo-viscous technology bulk-fill resin composite was to take the advantage of flowable composite and so decrease the polymerization shrinkage strain. Also, preheating of VisCalor bulk-fill resin composite to 65˚C has a superior effect to a degree on decreasing the polymerization shrinkage strain compared to high viscosity bulk-fill composite.

Many factors were found to have a direct effect on the polymerization shrinkage stresses as modulus of elasticity and molecular weight of the tested resin composite restorative materials. But polymerization shrinkage strain gives more accurate results.

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