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# Effect of preheating on polymerization shrinkage strain of BIS-GMA free and containing resin composite restorative materials (in vitro study)

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## Abstract

**Background:** This study investigated the effect of preheating of bulk-fill BIS-GMA free and containing resin composite on post-gel shrinkage strain. In a split Teflon mold, sixty resin composite specimens were prepared with dimensions 7 mm length × 4 mm width × 4 mm height. Thirty specimens of each tested restorative materials were prepared, ten specimens for each selected temperature used in the study (room temperature 23 °C, 50 °C and 65 °C). The resin composite was monitored for post-gel shrinkage strain for 3 min after light irradiation using strain gauges. For pairwise comparisons, Duncan's multiple range test was used to analyze the data after two-way ANOVA. The  $p \leq 0.05$  significance level was chosen.

**Results:** Viscalar thermoviscous bulk-fill composite Bis-GMA containing had the lowest polymerization shrinkage strain values in the three different temperatures. There was a statistically significant difference between groups according to material used at different temperatures. Both tested materials showed the highest shrinkage strain when preheated at 65 °C.

**Conclusions:** While the technology of thermoviscous is introduced to deliver the viscosity of a flowable resin composite so reducing the polymerization strain, it actually had adverse effect on it. Preheating of bulk-fill BIS-GMA free resin composite either to 50 °C or 65 °C had no effect on decreasing the polymerization shrinkage strain. Polymerization shrinkage strain of bulk-fill BIS-GMA contains resin composite either without or with preheating far superior to that of BIS-GMA free resin composite.

**Keywords:** BIS-GMA free composite, BIS-GMA containing composite, Polymerization shrinkage strain, Preheating

## Background

Patients' increasing demands for cosmetic restorations have expanded the usage of direct resin composites restoration for both anterior and posterior teeth. Polymerization shrinkage is the main drawback of resin composite, where stress of polymerization passed to the tooth, causing deformation that manifests as

enamel fracture, cracked cusps, cuspal displacement, interface adhesive failure, and restorative material micro-cracking (Giachetti et al. 2006). Bis-GMA (bisphenol A and glycidyl methacrylate) is the most widely used dimethacrylate monomer in resin composites due to its low polymerization shrinkage, low volatility, and high reactivity. However, the usage of Bis-GMA-based dental restorative materials has been questioned since estrogenic activity was discovered in a cell culture experiment (Nunez et al. 2015). Due to these unwanted effects, free methacrylate composite resins have developed, since they do not contain typical methacrylate in

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their formula. This lack of monomers allows for a contraction of less than 1% during polymerization, as well as increased biocompatibility, preventing any harmful consequences (Bacchi et al. 2015).

Polymerization shrinkage is the main drawback with bulk-fill resin composite, with volumetric polymerization shrinkage still ranging around 2% to 3%. Manufacturers of bulk-fill resin composites use several strategies to achieve deeper curing and lower shrinkage strains (Lins et al. 2019). One of the recent innovations in resin composite application involves preheating of resin composite material before insertion into the cavity. Preheating high viscosity bulk-fill composites could be a new way to accomplish a temporary viscosity reduction similar to that of a flowable composite without sacrificing the advantages of good mechanical properties associated with highly filled resin composites (Alshali et al. 2015). Reducing resin composite viscosity is the ways to improve restoration adaptability to the cavity, monomer conversion and decreasing the polymerization shrinkage. (Yang et al. 2019). The benefits of preheating composites may have an impact on daily restorative procedures as well, with the application of shorter light exposure to provide conversion values similar to those seen in unheated conditions (Pgdhnm et al. 2015).

Recently, a bulk-fill BIS-GMA containing resin composite with the thermoviscous technology was introduced. The manufacturer claims that it once warmed, delivers the viscosity of a flowable, then rapidly cools to body temperature once placed allowing for the immediate sculpt ability of a packable resin composite. As a consequence, the current study was conducted to determine the post-gel shrinkage strain (PGSS) of bulk-fill BIS-GMA containing and free resin composite preheated at 50 °C and 65 °C in comparison with without preheating at room temperature. The hypothesis is the polymerization shrinkage strain of preheated BIS-GMA free resin composite which was similar to that of bulk-fill thermoviscous BIS-GMA containing resin composite.

## Methods

VisCalor bulk and Admira fusion Xtra with Universal shade A3 were used for the study (Table 1).

A Teflon mold with dimensions (7 mm length × 4 mm width × 4 mm height) was used to produce standardized resin composite samples with equal sizes and dimensions. A foil electrical resistance strain gauge (Kyowa Electronic Instruments Co, LTD, Tokyo, Japan, Lot #Y4683M) was used to measure the strain of the resin composite specimens. The strain gauge consists of an insulating flexible backing which supports a metallic foil pattern. The gauge was 2 mm in length with electric resistance of 120 W and a gauge factor of  $2.13 \pm 1.0\%$ . As the object is deformed, the foil is deformed, causing its electrical resistance to change. The head of an electrical resistant strain gauge was fixed to a flat glass slab using a sticky tape and the hole of the Teflon mold was centralized and fixed over the strain gauge. The other side of the strain gauge was then connected to the strain monitoring device (Strain-Meter PCD-300A Kyowa-Electronic Instruments Co, LTD, Tokyo, Japan).

Sixty resin composite specimens were prepared and divided into two equal groups of 30 specimens each according to the type of resin composite tested. Each group was subdivided into three subgroups of ten specimens each according to tested temperatures (T) at room temperature  $23 \pm 2$  (T1), preheating at 50 °C (T2) and 65 °C (T3). The bulk-fill resin composite tube and compules were preheated in a heating device (Ceramic one input voltage 220v, output voltage 12v, power 24w, China) for 5 min (Elolimy 2020). The selected materials were preheated for 5 min each time. Viscalor bulk resin composite compule nozzle was applied perpendicular to the base of the mold, touched the strain gauge, and then injected in the mold. Admira fusion Xtra resin composite was packed into the cavity mold as one layer using gold-plated composite applicator. A Mylar polyester strip used for adaptation for both tested materials into the mold then the excess composite material was extruded using pressure applied through a glass slide that was then removed before composite curing.

**Table 1** Materials used, specification, composition, lot number and manufacturer

Material	Specification	Composition	Lot number	Manufacturer
VisCalor bulk	Thermoviscous composite bulk-fill (nano-hybrid composite) (Universal shade)	Matrix: Bis-GMA, aliphatic dimethacrylate Filler: Inorganic filler Filler content%: 83 (w/w)	2020095	Voco, Cuxhaven, Germany. service@voco.de
Admira fusion x-tra	ORMOCER®-bulk-fill nano-hybrid composite (universal shade)	Matrix: ORMOCER® Filler: glass ceramics, silica nanoparticles, pigments Filler content%: 84 (w/w)	2047160	

Strain gauge was directly connected to a strain-monitoring device (Fig. 1) (Strain-Meter PCD-300A Kyowa-Electronic Instruments Co, LTD, Tokyo, Japan). At first, the balance of device was zero. A light irradiation device (3 M ESPE, USA, 1200 mW/cm<sup>2</sup>) was used to cure the resin composite specimens according to their manufacturer’s instructions (10 s for viscalor and 20 s for admira fusion xtra).

For each experimental group (*n* = 10), strain measurements were collected during curing and 3 min after light irradiation. Strain versus time curves for the various testing conditions were obtained using strain meter software—PCD30-A (Kyowa-Electronic Instruments Co, LTD, Tokyo, Japan).

**Statistical analysis**

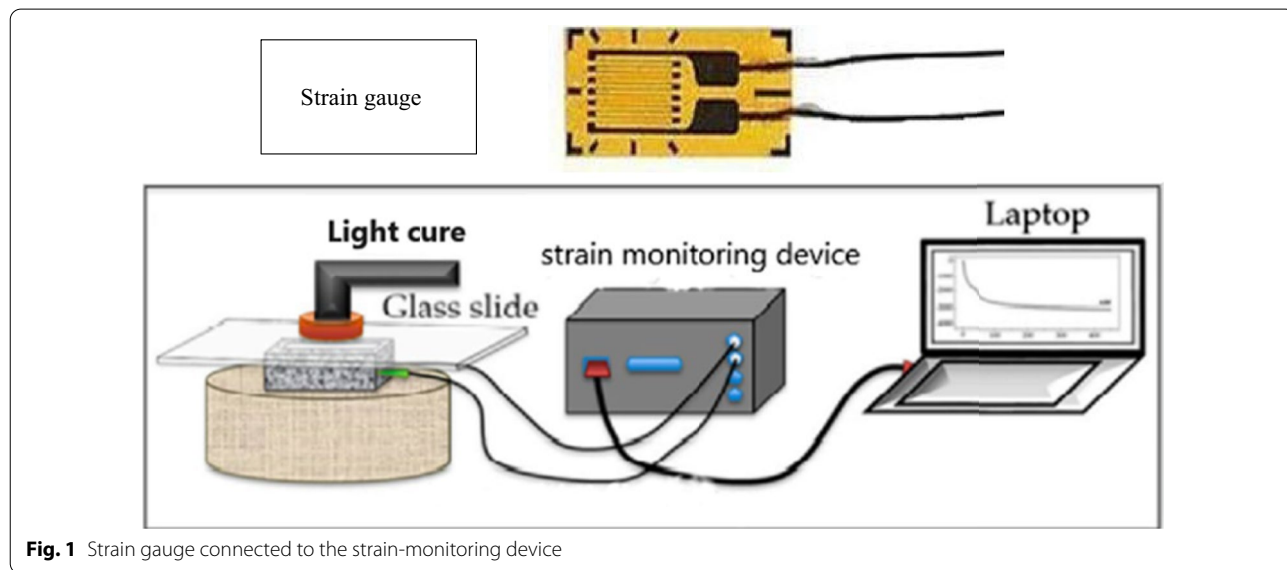
To check for normality, the Kolmogorov–Smirnov and Shapiro–Wilk tests were applied, and the findings revealed a parametric (normal) distribution. A one-way ANOVA was used to compare more than two groups in unrelated samples, followed by a Tukey post hoc test.

An independent sample t test was used to compare two groups in unrelated samples. The significance level was set at *p* ≤ 0.05.

**Results**

Table 2 and Figs. 2 and 3 showed the influence of temperature on post-gel polymerization shrinkage strain of different groups. Regarding the effect of the different tested resin composite restorative materials, there was a statistically significant difference in the mean values of polymerization shrinkage strain between the two tested resin composite at the different preheating temperatures (*p* < 0.001), where Bis-GMA free resin composite (A2 group) showed the higher mean post shrinkage values (A1 group).

In Bis-GMA containing resin composite (A1 group), there is no statistically significant difference in the polymerization shrinkage strain between (T1) and (T2), while there was a statistically significant difference between (T1 and T3) and likewise between (T2 and T3)



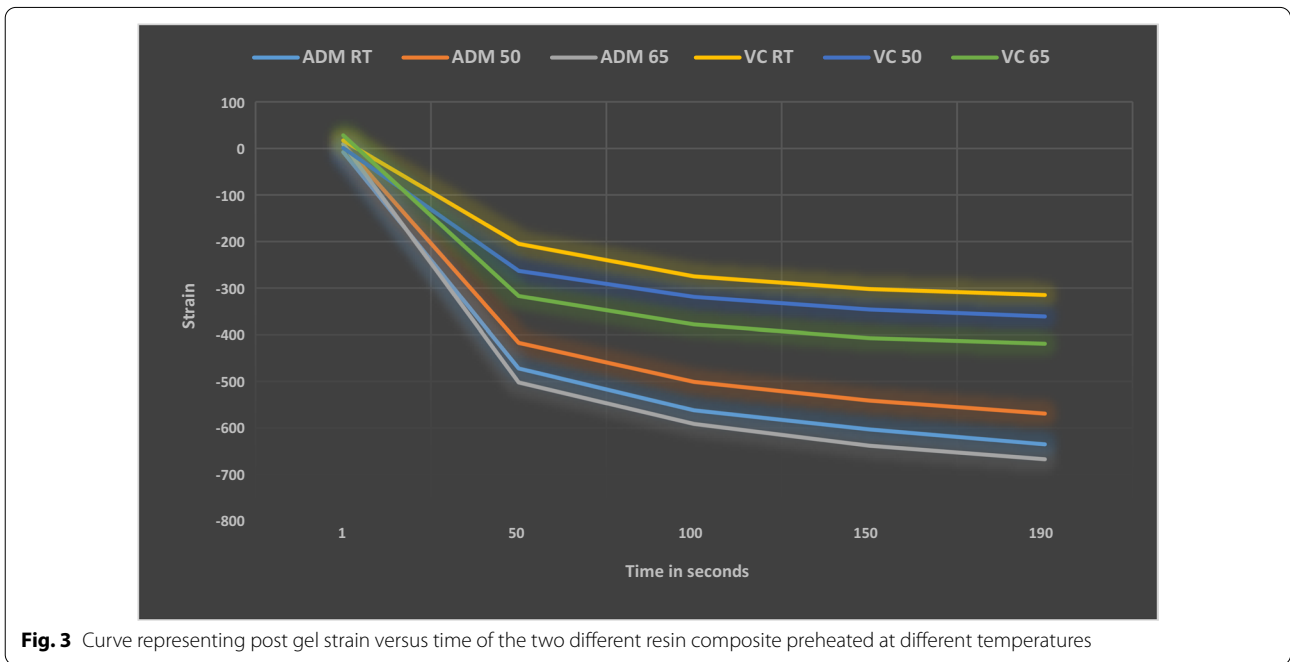
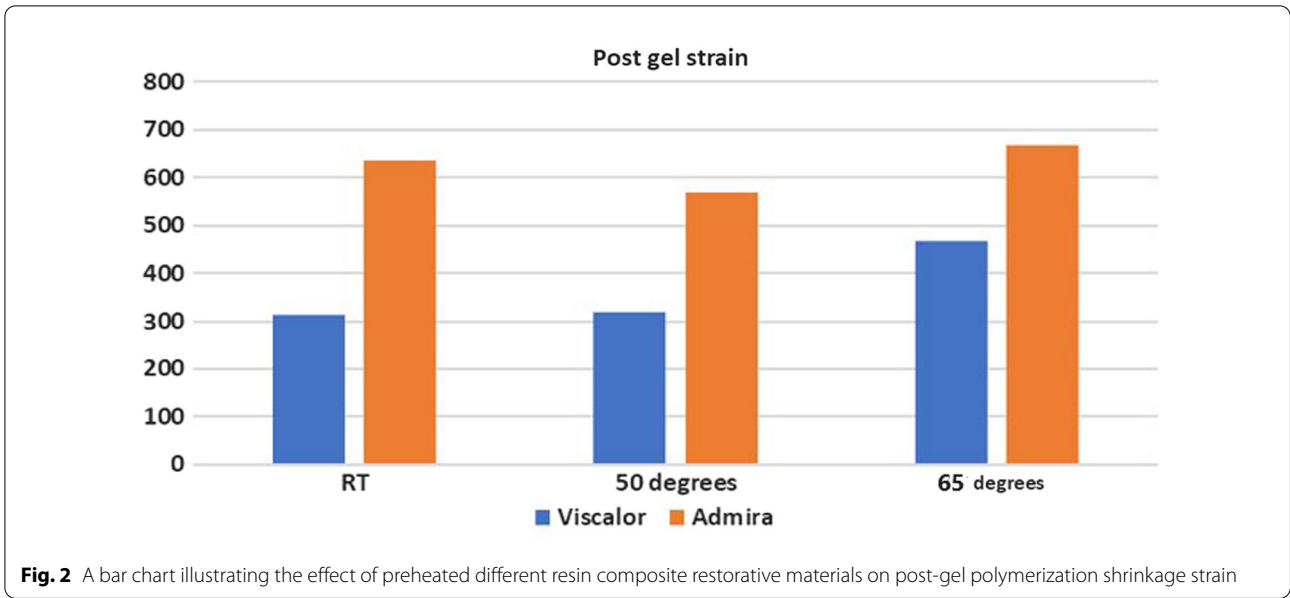
**Fig. 1** Strain gauge connected to the strain-monitoring device

**Table 2** Effect of temperature on post-gel polymerization shrinkage strain of different groups

Post-gel polymerization shrinkage strain	Heating temperature						<i>p</i> value
	T1		T2		T3		
	Mean	SD	Mean	SD	Mean	SD	
Viscalor (A1)	− 314.00	17.82	− 321.00	24.85	− 468.00	12.04	< 0.001*
Admira (A2)	− 635.00	54.77	− 569.00	51.16	− 667.00	80.51	0.082 ns
<i>p</i> value	< 0.001*		< 0.001*		0.001*		

ns: non-significant (*p* > 0.05)

\*Significant (*p* < 0.05)



where ( $p < 0.001$ ), and the highest mean value was found in (T3).

For Bis-GMA free resin composite (A2 group), there was no statistically significant difference in the post-shrinkage strain at all tested temperatures. (T1 and T3) ( $p = 0.082$ ). The difference between T2 and both

T1 and T3 was statistically significant, while T3 having the greatest mean value.

## Discussion

Bulk-fill composite resins have been launched in the dental market as a new restorative concept. It is highly filled viscous resin composite restoration which can fill a posterior cavity with depth 4 to 5 mm. Highly viscous bulk-fill resin composite has many advantages over the low viscosity resin composite. It has high filler content, superior mechanical properties and easier in application as it does not need incremental coverage. In addition, it contains superior features such as pre-polymer stress relievers, polymerization modulators and modified high-molecular-weight base monomers to minimize the polymerization shrinkage stresses. Although these changes in composition have been introduced to allow greater conversion at increasing depths, they also potentially enhance the mechanical properties, volumetric shrinkage and other related properties, including the clinical performance of the materials (Ilie et al. 2014). It was agreed that higher fillers content of the viscous resin composite results in increasing stiffness of the material in the pre-gel phase and increase the total volumetric shrinkage stresses. In addition, the polymerization rate of highly viscous bulk-fill composites is low.

Polymerization shrinkage is the main drawback of resin composite (Bis-GMA containing), where stress of polymerization passed to the tooth, causing deformation that manifests as enamel fracture, cracked cusps, cuspal displacement, interface adhesive failure, and restorative material micro-cracking (Giachetti et al. 2006).

Due to these effects, free methacrylate composite resins have developed, since they do not contain typical methacrylate in their formula. This lack of monomers allows for a contraction of less than 1% during polymerization, as well as increased biocompatibility, preventing any harmful consequences (Bacchi et al. 2015). Organically modified ceramics (Ormocer) were developed as Bis-GMA-free resin composite materials have been more recently introduced for direct restorations. Ormocer is the acronym for organically modified ceramic and comprises inorganic–organic co-polymers with inorganic silanated filler particles. It generally showed reduced volumetric shrinkage and shrinkage stress, lower or similar wear resistance, and intermediate strength, fracture toughness, or elastic modulus when compared to conventional resin composites. Until now, only one brand of this recent generation of pure Ormocer composite resin marketed as Admira Fusion-Ormocer (Klauer et al. 2019). It also lacks cytotoxicity associated with conventional monomers, such as Bis-GMA and TEGDMA. A fact that proves to be a great advantage when compared to methacrylate-based composite resins. So, it is considered inert and improves the biocompatibility (El-Askary et al. 2020).

Preheating resin composites have found to reduce the polymerization shrinkage as the increased temperature reduces the viscosity of the material and increases radical mobility. Thereby, the benefits of preheating composites may have an impact on daily restorative procedures as well, with the application of shorter light exposure to provide conversion values similar to those seen in unheated conditions. So that improves adaptation also results in increased polymerization and higher degree of conversion (Baroudi and Mahmoud 2015).

Preheating of the resin composites exhibited significant decrease in film thickness after preheating, thus enhancing flow due to the thermal energy that increases the molecular motion of the monomer chains within the composite and also increases the radical collision frequency, and propagation is allowed to continue for a longer time before the onset of deceleration, increasing conversion and shrinkage (Deb et al. 2011).

To have the advantage of preheating to the resin composite before packing, a bulk-fill BIS-GMA containing resin composite with the thermoviscous technology which has been specially developed for warming up to become less viscous, allowing for application similar to that for a flowable material. As a consequence, the current study was conducted to determine the post-gel shrinkage strain (PGSS) of bulk-fill BIS-GMA containing (Viscalor, thermoviscous resin composite) and bulk-fill BIS-GMA free resin composite (Admira fusion Xtra) preheated at 50 °C and 65 °C in comparison with without preheating at room temperature  $23 \pm 2$  °C.

Both types of the composite resin restorative materials were heated for 5 min after stabilization of each selected heating temperature so as to accomplish the most extreme present temperature (Elolimy 2020). The mold was prepared of the Teflon material that not adheres to the resin composite, thus permitting its free shrinkage. The measurement of polymerization shrinkage strain has been done by using the strain monitoring device that is a simple and available approach to determine the post-gel shrinkage strain. The strain was recorded for only 3 min after curing time, as the polymerization kinetic curves of preheated resin composite restorative materials from 0 to 15 min were equivalent for different preheating times and irradiation durations (Yang et al. 2020).

The results of this study showed that regarding the effect of different resin composite used in the study, there was a statistically significant difference in the mean value of polymerization shrinkage strain between (Group A1) and (Group A2) at the three different preheating temperatures, and the mean value of polymerization shrinkage strain of admira fusion xtra was higher than that of viscalor bulk resin composite.



This result was in agreement with Xu et al. (2020), Monsarrat et al. (2017) and Kournetas et al. (2004), where BIS-GMA containing composite presented the lowest shrinkage strain than BIS-GMA free composite, and Admira fusion showed the highest degree of conversion (DC) and the value of polymerization shrinkage strain was significantly higher than that of other resin composites containing BIS-GMA tested. They attributed that to the chemical composition of the resin matrix that has a significant impact on the magnitude and kinetics of shrinkage strain, as well as the development of elastic modulus. Resin composite containing BIS-GMA has high molecular weight than that of resin composite free BIS-GMA (admira fusion), and the shrinkage strain values of resin matrixes created with high molecular weight (Mw) monomers were lower than those formulated with low Mw monomers (Peutzfeldt 1997).

This result was in discordance with Taubock et al. (2018) and Lins et al. (2019), as the bulk-fill resin composites based on Ormocer (Bulk Ormocer) had the lowest linear polymerization shrinkage and shrinkage force that was attributed to its resin system, which consists of inorganic–organic copolymers rather than traditional monomers (e.g., Bis-GMA, UDMA and TEGDMA).

Concerning of the effect of resin composite preheating temperature, the polymerization shrinkage strain of both types of tested resin composite increased with the increase in preheating temperature as the highest mean value of polymerization shrinkage strain was found at (T3). To promote flow and adaptability, preheating the composites exposed to high temperatures (54 °C or 68 °C) induces volumetric shrinkage (Walter et al. 2009).

These results were in agreement with (El-Korashy 2010) that preheating resin composites before application enhanced its DC while also increased its post-gel shrinkage strain (PGSS). Three concurrent reasons may be responsible for the considerable rise in PGSS of all pre-warmed composite resin groups relative to room temperature groups. First, because of a higher rate of polymerization as a result of preheating and promptly reaching the gel point, there was likely a rapid stress buildup within the composite. Second, due to the increased DC values caused by preheating, the volumetric shrinkage and elastic modulus of the material increases. Third, combined with polymerization shrinkage, the effect of substantial thermal shrinkage of the warmed composite as it cools to room temperature may contribute to the dramatic increase in generated stresses.

This result was in disagreement with (Deb et al. 2011) as pre-warming dental composites improve linear polymerization shrinkage, flow, and the degree of conversion, and also with (Lohbauer et al. 2009) as they found that preheating did not significantly increased the

polymerization strain. Also (Yang et al. 2020) reported that preheating had no negative effects due to premature polymerization.

## Conclusions

Within the limitations of this research, it was probable to draw the following conclusions:

The polymerization shrinkage strain of the thermoviscous bulk-fill BIS-GMA containing resin composite without preheating was limited in comparison with that of bulk-fill BIS-GMA free. While the technology of thermoviscous introduced to deliver the viscosity of a flowable resin composite so reducing the polymerization strain, it actually had adverse effect on it. Preheating of bulk-fill BIS-GMA free resin composite either to (50 °C or 65 °C) had no effect on polymerization shrinkage strain. Polymerization shrinkage strain of bulk-fill BIS-GMA free resin composite either without or with preheating exceeds that of BIS-GMA containing resin composite. As the polymerization shrinkage stresses is affected by many factors as molecular weight and modulus of elasticity of the tested materials so depending on the strain results is more accurate.

## Abbreviations

Bis-GMA: Bisphenol A-glycidyl methacrylate; Ormocer: Organically modified ceramics; PGSS: Post-gel shrinkage strain; UDMA: Urethane dimethacrylate; TEGDMA: Triethylene glycol dimethacrylate.

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Not applicable.

## Authors' contributions

ML, MIR and NAM performed the study design. ML performed the whole methodology. ML, MIR and NAM analyzed the data. ML, MIR and NAM were the major contributors in writing the manuscript. All the authors read and approved the final manuscript.

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## Availability of data and materials

The authors announce that the data supporting the results of this study are existing within the article.

## Declarations

### Ethics approval and consent to participate

Not applicable.

### Consent for publication

Not applicable.

### Competing interests

The authors declare that they have no competing interests.

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