

IMPLICATION OF PREHEATING ON THE MICROHARDNESS OF GIOMER-BASED BULK-FILL VERSUS CONVENTIONAL BULK-FILL RESIN COMPOSITE: AN IN-VITRO STUDY

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ABSTRACT

Introduction: Bulk-fill composite resin, a recently developed restorative material, gained widespread use due to its claimed decreased rate of polymerization shrinkage, increased depth of cure up to 4 mm, decreased restoration time, enhancement of marginal compatibility, and increased bonding ability to dentin. Giomer-based bulk fill is a light-cured restorative material that uses pre-reacted glass-giomer (PRG) filler technology to achieve faster, single-increment (up to 4 mm) placement in posterior teeth. This hybrid material is said to combine the strengths of both composite resins (aesthetics, strength) and glass ionomers (fluoride release) for improved clinical outcomes and efficiency.

Materials and Methodology: In this study executed in vitro, 42 specimens were put together using Ivoclar Tetric-n-Ceram bulk fill (conventional) and Shofu Beautifil bulk restorative material (giomer-based), for a total of 84 disk-shaped specimens for microhardness testing. The specimens were allocated into 4 groups: Group 1: Ivoclar Tetric-n-Ceram bulk fill with preheating (at 68°C for 15 minutes); Group 2: Ivoclar Tetric-n-Ceram bulk fill without preheating. Group 3: Shofu Beautifil bulk restorative with preheating (at 68°C for 15 minutes); Group 4: Shofu Beautifil bulk restorative without preheating. Microhardness assessment by Vickers test employing a diamond indenter. Statistical comparisons were performed using SPSS software.

Results: Preheating of both Conventional and giomer-based bulk-fill composites to a temperature of 68°C appears to significantly improve the microhardness, but the microhardness of conventional bulk-fill was higher compared to giomer-based bulk-fill.

Conclusion: Preheating bulk-fill composites upto 68°C improved the microhardness. Substantial variations in the parameter were discovered across different bulk-fill composites, primarily stemming from inherent variations in their chemical constitutions.

KEYWORDS: Composite resins, Preheating, Microhardness, Flexural strength, Restoration

INTRODUCTION

Over the last decade, the application of direct resin composites in routine clinical practice has expanded significantly, largely driven by increasing patient expectations for esthetic dental restorations [1]. Composite resins provide superior physical and chemical qualities, better handling qualities, along with better aesthetic results as contrasted to conventional restorative materials like silver amalgam. Nevertheless, volumetric shrinkage is intrinsically linked to the polymerization process during curing. With documented shrinkage values ranging from roughly 2.7% to 7.1%, this effect is especially noticeable in widely used bis-methacrylate-based composite resins [2]. The ensuing polymerization stress may cause bond failure and a number of unfavorable clinical outcomes, such as the development of interfacial gaps between the composite resin and the cavity walls, enamel fracture, and microcracks within the restorative material. [3]. These gaps can compromise the restoration's long-term success by making it more susceptible to secondary caries and postoperative sensitivity. [4]. In addition, the inherent stickiness and increased viscosity of composite resins make handling and manipulation challenging. As a result, their modest adaptation to the prepared cavity walls might not prove adequate. [5]. Owing to their superior flow characteristics, flowable composite resins may help minimize interfacial gaps between the prepared cavity

walls and the restoration [6]. Their lower filler concentration, yet, may cause more polymerization shrinkage, which could jeopardize the restoration's mechanical qualities. [7]. The employing of a flowable composite liner in combination with traditional composite resins has been explored as a solution to this constraint [1,8] [1]. Additionally, a revolutionary method to improve the handling and adaptability of standard composite resins is to preheat them with an external warming device before polymerization. [9].

A photoinitiator system consisting of photosensitizers and accelerators incorporated into light-cured resin composites is frequently used in routine clinical practice [10] [11]. When exposed to a particular wavelength of light, the photosensitizer creates free radicals in the composite resin, which starts the polymerization process [7]. These free radicals then interact with monomer molecules to create more reactive species, which initiate a chain reaction that eventually initiates the resin matrix and diluent to polymerize and cure. [6]. Preheating resin composites has been shown to improve both the rate of monomer conversion and the mechanical properties of the material [12]. Recent studies have demonstrated that preheating resin composites can increase the degree of conversion by lowering material viscosity, facilitating free radical mobility, and increasing the likelihood of interactions between unreacted functional groups and free radicals. [9]. Preheating composite resins has been shown to enhance both the rate of monomer conversion and the mechanical properties of the material [9]. The application of thermal energy causes the viscosity to decrease by increasing molecular separation between monomers and oligomers, which makes it less challenging for them to pass one another [3]. Theoretically, the enhanced flow of prewarmed composite resins encourages better uncured material adaptation to the prepared cavity walls and could help lower marginal leakage [4]. Additionally, heating significantly decreases film thickness while increasing material fluidity, which enhances cavity adaptation and improves the seal established between the resin composite and the tooth structure [13].

Preheating composite resins can improve marginal adaptation and increase the degree of monomer conversion, but it may also cause more polymerization shrinkage, which can negatively affect microleakage [14] [15]. Thereby, to ascertain the clinical viability of composite resins, a methodical examination of how preheating affects them is necessary. Better mechanical properties, increased monomer conversion, and improved marginal adaptation are a handful of the suggested attributes of composite preheating [16] [11]. Owing to these potential benefits, this technique has gained increasing acceptance among dental practitioners.

Combination of resin matrix with pre-reacted glass-ionomer (PRG) fillers, which are particles created by reacting a glass-ionomer filler with polyacrylic acid. The filler particles are also typically silanized and stabilized to ensure a strong bond with the resin matrix [17]. A hybrid composition providing the aesthetic and physical advantages of composite resins in conjunction with the fluoride-releasing and recharging properties of glass ionomers [17]. Contemplating the scarce information accessible where bulk-fill composites and their modifications are solely studied alongside the implications of preheating on their properties, the present *in vitro* study was envisioned to learn about the effect of preheating on the microhardness of two bulk-fill resin composites. Beautifil bulk restorative (Shofu, Japan), a giomer-based bulk-fill and Ivoclar Tetric N-Ceram bulk fill (Ivoclar Vivadent, Schaan, Liechtenstein), a conventional bulk-fill. The null hypothesis pursued in this study was that there are no variances in the microhardness of the preheated as opposed to non-preheated composite samples.

MATERIALS AND METHODOLOGY:

For determination of sample size, reference was taken from the study of Lucey et al. G-Power version 3.1.9.6 was used for sample size determination. A requisite sample size of seventeen per group was established leveraging 95% confidence, 80% test power, and a two-tailed test. To strengthen the study power, the sample size was extended to 21 samples per group (20% increase). A total of 168 samples were recruited in this investigation.

Two bulk fill resin composites-Beautifil bulk restorative (Shofu, Japan), a giomer-based bulk-fill and Ivoclar Tetric N-Ceram bulk fill (Ivoclar Vivadent, Schaan, Liechtenstein), a conventional bulk fill-were used in the study. The AdDent Calset warmer (AdDent, Inc., Connecticut, USA) was used for preheating composite resin. 84 disk-shaped samples were prepared, and the preparation temperature of 24°C was kept for conventional bulk-fill, and a temperature of 68°C was selected as the preheating temperature, with every group comporting 21 samples, with a diameter of 4 mm and a thickness of 2 mm.

Samples were allocated into 4 groups: Group A- Conventional bulk fill with preheating, Group B- Conventional bulk fill without preheating, Group C-Giomer-based bulk fill with preheating, and Group D- Giomer-based bulk fill without preheating.

The composites were nestled in an aluminum mold with a 4 mm x 2 mm thickness. A plastic strip and a glass slide were placed on them to skim the excess material. Then they were cured with an LED light cure device—Woodpecker iLED plus (Guilin Woodpecker Medical Instrument Co. Ltd., China) at an intensity of 2000 mw/cm² for 20 seconds. After polymerization, the samples were retrieved from the mold, and a 600-grit silicon carbide abrasive was employed to trim the excess material, and the dimensions of all samples were quantified using a digital caliper (Super Caliper; Mitutoyo Corporation, Kanagawa, Japan).

Samples were subjected to the Vickers microhardness test post-thermocycling for 14 days using the HMV-G series microhardness tester (Shimadzu Corporation, Japan). Microhardness of the undersurface was checked rather than the superficial surface in order to examine the claim of enhanced depth of cure achievable with preheating. Subsequent to positioning the samples in a holder, the surface was set perpendicular to the pyramidal indenter having a square base. A load of 100 grams was applied with a holding time of 15 seconds.

Statistical analysis-

The results were computed by descriptive statistics mean and standard deviation. The Shapiro-Wilk test was employed to test the distribution of quantitative variables. In order to compare microhardness between preheated and control groups, one-way analysis of variance (one-way ANOVA) was performed. A probability value of less than 0.05 was interpreted as significant. Tukey's HSD post hoc was done on obtaining a significant ANOVA to pinpoint exactly which group means differ from each other, controlling the overall Type I error that arises from making multiple comparisons. Statistical Package for Social Sciences (SPSS) for Windows, version 16.0 (SPSS Inc., Chicago, IL, USA), was chosen for statistical analysis.

RESULTS

The mean microhardness in both preheated groups was higher in comparison to the mean microhardness of non-preheated groups. Among preheated groups, the mean microhardness of Group A (conventional bulk fill with preheating) was higher than the mean microhardness of Group C (giomer-based bulk fill with preheating). Groups B and D (non-preheated groups) failed to show any statistically significant difference in mean microhardness. One-way ANOVA reported a statistically significant difference in microhardness among the four experimental groups ($p < 0.05$). (Table 1 & table 2).

Table 1: Tests of normality

		Kolmogorov-Smirnov			Shapiro-Wilk		
	Group	Statistic	df	Sig.	Statistic	df	Sig.
MICROHARDNESS VALUE (VHN)	A	0.144	21	0.200*	0.956	21	0.443
	B	0.139	21	0.200*	0.966	21	0.645
	C	0.089	21	0.200*	0.958	21	0.478
	D	0.190	21	0.047	0.908	21	0.050

Table 2: Microhardness value (VHN)

GROUP	Mean	N	Standard deviation	Standard error of Mean
A	54.033	21	2.6475	0.5777
B	25.329	21	2.9858	0.6516
C	48.543	21	4.2832	0.9347
D	24.571	21	3.0576	0.6672
Total	39.119	84	12.7808	1.5036

Tukey's HSD post-hoc analysis showed that Group A exhibited significantly higher microhardness values than Groups B, C, and D. The microhardness was in the order: Group A > Group C > Group D $\approx$ Group B. (Table 3 and 4 ; Figure 1)

Table 3: Tukey's HSD

		Subset for alpha = 0.05		
GROUP	N	1	2	3
D	21	24.571		
B	21	25.329		
C	21		48.543	
A	21			54.033
Sig.		0.879	1.0000	1.0000

Table 4: Tukey's HSD post hoc analysis

(I)GROUP	(J)GROUP	Mean difference(I-J)	Standard error	Sig.	95% Confidence interval	
					Lower bound	Upper bound
A	B	28.7048	1.0191	0.000	26.031	31.379

	C	5.4905	1.0191	0.000	2.817	8.164
	D	29.4619	1.0191	0.000	26.788	32.136
B	A	-28.7048	1.0191	0.000	-31.379	-26.031
	C	-23.2143	1.0191	0.000	-25.888	-20.540
	D	0.7571	1.0191	0.879	-1.917	3.431
C	A	-5.4905	1.0191	0.000	-8.164	-2.817
	B	23.2143	1.0191	0.000	20.540	25.888
	D	23.9714	1.0191	0.000	21.297	26.645
D	A	-29.4619	1.0191	0.000	-32.136	-26.788
	B	-0.7571	1.0191	0.879	-3.431	1.917
	C	-23.9714	1.0191	0.000	-26.645	-21.297

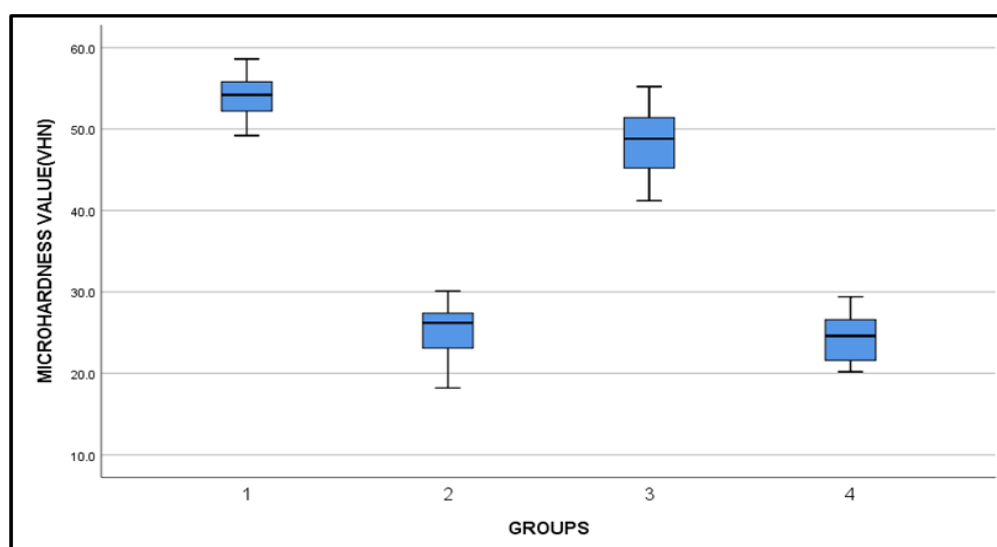


Figure 1: Microhardness based on the type of composite and the intervention

DISCUSSION

Friedman was the first to use preheating in 2001, with the goals of improving adaptation, increasing mechanical properties, reducing stress, and shortening curing time. In the current investigation, preheating achieved a substantial effect on the microhardness of Ivoclar Tetric N-Ceram bulk fill and Beautifil bulk restorative bulk fill composites [1]. The conversion of the top and bottom surfaces of the resin sample can be substantially enhanced by heating the composite resin preceding light curing, enabling equal conversion with a shorter exposure period. Whilst greater temperatures cause the composite resin to become less viscous and improve radical mobility, culminating in more polymerization processes and faster conversion rates, lower exposure conduces to fewer free radicals being generated. [11]. One of the criteria to characterize the mechanical properties of restorative materials at the completion of the procedure is the degree of conversion. Microhardness, wear tolerance, fracture resistance, and flexural strength are all reduced with a lower conversion degree. [13]. Likewise, it has been discovered that heating composites prior to curing can enhance polymerization and degree of conversion by essentially decreasing viscosity. [18].

An investigation carried out by Lucey et al.'s study reported that preheating ameliorated the microhardness of the hybrid (conventional) Spectrum TPH composite [15]. In accordance with Degirmenci and Can's investigation, the microhardness increased in Bulk Fill composites as a consequent result of preheating, while it decreased in micro-hybrid composites [19]. An investigation conducted by Theobaldo et al. discovered that preheating had no detrimental effect on the microhardness of Surefil SDR bulk composite. Interestingly, despite the conventional flowable composite Filtek Z350 (used as a control group) having a higher volume percentage of filler (55%), its lower monomer-to-polymer conversion degree compared to the preheated bulk fill flow composite culminated in remarkably comparable microhardness values, making it evident that various factors influence the microhardness

of composite resin materials [20]. In the course of their inquiry, Nada and El-Mowafy found that the brand of the composite, its chemical composition, and in particular the kind of monomer utilized all impact the manner in which preheating influences the surface microhardness of composites [21].

In alignment with some earlier research that found heating composites before curing enhanced polymerization kinetics and could contribute to higher monomer conversion by increasing chain mobility, preheating the present investigation produced a significant variance in the microhardness of both bulk fill resin composite outcomes. Tetric N-Ceram Bulk Fill demonstrated consistently higher microhardness values than Beautifil Bulk Restorative when preheated. This difference could correspond to compositional variations, particularly filler content, particle morphology, and the type of resin matrix. Microhardness values are strongly influenced by filler size, distribution, and volume fraction. In accordance to Degirmenci and Can's study, Estelite Bulk Fill Flow composite (EST), which integrates BisGMA monomer and exhibited higher microhardness values versus G-aenial Posterior along with SDR Plus composites. BisGMA is a monomer with high molecular weight, strong hydrogen bonding capacity, and low molecular mobility. It is characterized as the most viscous and least flexible between dental resin monomers. The strong intermolecular bonding that links hydroxyl groups in BisGMA likely led to the higher microhardness of EST.

The Vickers or Knoop tests can be employed for assessing the microhardness of resin composites. Utilizing a diamond tip along with a predetermined force for a specific period of time, both techniques generate an indentation [21,22]. The Vickers test was employed during this investigation to assess the surface microhardness. Research has shown that the Knoop as well as Vickers hardness tests have a very significant correlation ($r=0.991$) [23]. The Knoop test is centered on linear measurements, whilst the Vickers test measures values anchored on an area [22]. As a result, it is challenging to pinpoint which test is more accurate, and any test can be used for material comparisons.

LIMITATIONS

Note that samples were studied 14 days after curing, and the study only looked at two composite brands and two preheating temperatures. Future research might investigate different bulk-fill composite brands, a broader spectrum of preheating temperatures, and various post-curing time frames, all of which might yield distinct results. Further, the results possibly have been influenced by the samples' non-anatomical shape, which was put together in accordance with ISO standards. The samples were solely polymerized from a single side with the aim to more accurately mimic the clinical environment. Also, as no dental tissue was used in this in vitro investigation, the outcomes could differ in clinical circumstances. By evaluating composites with dental tissue engaged, upcoming studies might investigate the impact of preheating on pulp and dental tissue.

DECLARATIONS

Data Availability Statement: All data relevant to the study are included in the manuscript.

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CONCLUSION

In light of the preliminary results from this study, it can be speculated that preheating bulk-fill composites to a temperature of 68 degrees Celsius does not negatively impact their microhardness (undersurface).

In fact, it results in an increase in their microhardness (undersurface). Additionally, substantial variations in both microhardness and flexural strength are observed among different bulk-fill composites, primarily stemming from peculiarities in their chemical compositions. Within the constraints of this in vitro investigation, the improved handling characteristics of preheated composites, such as reduced viscosity and better cavity adaptation leading to improved microhardness, are advantageous. Even if the mechanical properties are not substantially altered, the potential for enhanced marginal adaptation and reduced void formation may indirectly support restoration longevity. This difference in the mechanical properties undergoing the same treatment underscores the role of resin chemistry and filler composition in dictating mechanical outcomes. Clinically, preheating can be advocated for improved handling and adaptation while recognizing that performance remains material-dependent

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