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# THE EFFECT OF PREHEATING AT 39$^{O}$ AND 60$^{O}$ ON COMPRESSION STRENGTH OF BULK-FILL COMPOSITE RESIN

*PENGARUH PREHEATING PADA SUHU 39$^{O}$ DAN 60$^{O}$ TERHADAP KEKUATAN KOMPRESI RESIN KOMPSIT BULK-FILL*

**Original Research Article**
*Penelitian*

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**A B S T R A C T**

***Background:*** *The incremental placement technique for composite resin may lead to bond failures and air entrapment between resin layers. Bulk-fill composite resin, which can be applied to cavities depths of up to 4 - 5 mm, is expected to have good compressive strength so that it can resemble natural tooth structures.* ***Purpose:*** *This study aimed to evaluate the effect of preheating on the compression strength of bulk-fill composite resins at 39°C and 60°C.* ***Method:*** *This research type was a laboratory experiment employing a post-test control group design. A total of 27 cylindrical bulk-fill composite resin specimens were divided into three groups: group 1 was preheated at 39°C, group 2 at 60°C, and group 3 served as the control group. The samples were then immersed in distilled water and stored in an incubator at 37°C for 48 hours. Compressive strength test was measured using a Universal Testing Machine.* ***Result:*** *One-way ANOVA statistical test showed that there were significant differences in the three groups (p-value < 0.05). A post-hoc Bonferroni test was carried out to compare between groups and indicated a significant difference between the 60$^{0}$ preheated group and the control group.* ***Conclusion:*** *Preheating at 39°C and 60°C affects the compression strength of bulk-fill composite resin.*

**A R T I C L E  I N F O**

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*Bulk-fill composite resin, Compression strength, Preheating*

**A B S T R A K**

**Latar belakang:** Resin komposit yang diaplikasikan dengan teknik inkremental memiliki kekurangan adanya kegagalan ikatan dan kontaminasi udara antar lapisan resin. Resin komposit *bulk-fill* yang dapat diaplikasikan pada kavitas dengan ketebalan maksimal 4 - 5 mm diharapkan memiliki kekuatan kompresi yang baik sehingga dapat menyerupai struktur gigi asli. **Tujuan:** Penelitian ini bertujuan untuk mengetahui pengaruh *preheating* pada suhu 39°C dan 60°C terhadap kekuatan kompresi resin komposit *bulk-fill*. **Metode:** Penelitian ini merupakan jenis eksperimental laboratoris dengan rancangan *post-test with control group design*. Sampel yang digunakan pada penelitian ini yaitu 27 resin komposit *bulk-fill* berbentuk silindris yang terbagi menjadi 3 kelompok. Kelompok 1 yaitu resin komposit yang di-*preheating* pada suhu 39°C, kelompok 2 yaitu resin komposit yang di-*preheating* pada suhu 60°C, dan kelompok 3 yaitu kelompok kontrol. Sampel yang sudah dicetak direndam dalam akuades dan disimpan dalam inkubator pada suhu 37°C selama 48 jam. Dilakukan uji kekuatan kompresi menggunakan *Universal Testing Machine*. **Hasil:** Uji statistik *One-way ANOVA* menunjukkan adanya perbedaan bermakna pada ketiga kelompok (*p-value* < 0.05). Uji *post-hoc Bonferroni* dilakukan untuk membandingkan antar kelompok dan dihasilkan perbedaan signifikan antara kelompok perlakuan *preheating* suhu 60°C dan kelompok kontrol. **Kesimpulan:** Terdapat pengaruh preheating pada suhu 39°C dan 60°C terhadap kekuatan kompresi resin komposit *bulk-fill*.

**Kata kunci:**
Resin komposit *bulk-fill*, Kekuatan kompresi, *Preheating*

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## INTRODUCTION

Composite resin is one of the materials that is most frequently utilized in dental restoration operations due to its excellent durability and aesthetic quality (Cheng *et al*., 2022). Composite resin is typically applied in layers, with a maximum thickness of 2 mm for each layer. However, this incremental technique is time-consuming and may result in interlayer gaps, increasing the risk of bond failure and air entrapment between resin layers (Hatrick, 2016; Yudistian, 2022). A restorative substance called bulk-fill composite resin was developed to overcome these shortcomings. Cavities up to 4 - 5 mm thick can be filled using bulk-fill composite resin in a single polymerization step (Randolph *et al*., 2018). This is possible due to the deep cure depth, low polymerization shrinkage, and higher translucency level of bulk-fill composite resin, which facilitates easier light transmission during the polymerization process (Haugen *et al*., 2020). Designed primarily for posterior tooth restorations, bulk-fill composite resins are expected to withstand masticatory loads. Compressive strength—often referred to as compression strength—is therefore a critical property, as it reflects the material's ability to resemble natural teeth (Akarsu and Aktuğ Karademir, 2019).

According to Bhat *et al*. (2019), a decent restoration material should have a compression strength range of 300 – 380 MPa, which is comparable to that of enamel and dentin. According to Sakaguchi *et al*. (2016), composite resins typically have compressive strength values between 200 to 450 MPa. The bulk-fill method yields an average compression strength of 191.65 MPa for composite resin, according to a study by Mundung *et al*. (2018). Similar studies by Mofidi *et al*. (2020) revealed that bulk-fill composite resin had an average compression strength of 250.5 MPa. The findings from both trials indicated that the compressive strength of bulk-fill composite resins was inadequate. When compared to enamel and dentin, the strength of the composite resins was much lower, so it has the potential to break easily if subjected to strong pressure from chewing.

The process of polymerization can be influenced by various things. Imam *et al*. (2020) reported that raising the temperature of the resin optimizes polymerization, leading to a higher degree of conversion and increased polymer cross-linking, which enhances material solidification. Preheating has therefore been suggested as a method to improve the material's mechanical and physical properties, including surface hardness, microleakage, and compression strength (AlShaafi, 2017).

Several studies have demonstrated how preheating affects the characteristics of composite resin. According to research by Khaerani (2022), bulk-fill composite resin's surface hardness can be considerably raised by preheating it to 39°C. Similarly, Ramadhan (2021) found that bulk-fill composite resin microleakage can be minimized by preheating at 60°C. However, this study's findings do not address the difference between 39°C and 60°C in terms of the bulk-fill composite resin's compression strength. Therefore, the purpose of this study is to know the effect of preheating bulk-fill composite resin at 39°C and 60°C on compression strength.

## MATERIAL AND METHOD

This laboratory experimental study employed a post-test control group design. The specimens were cylindrical bulk-fill composite resin. In this study using the Federer method, the number of samples used was calculated to be nine samples for each group. However, due to outliers identified during data analysis, the final sample size was adjusted to eight specimens per group. In total, there were three treatment groups. As the control group, (1) Group 1 comprises composite resin that was preheated to 39°C, (2) Group 2 comprises composite resin that was preheated to 60°C, and (3) Group 3 consists of composite resin that was not preheated.

A cylindrical polyurethane mold was prepared with a thickness of 2 mm and a diameter of 5 mm. 1 composite resin syringe (Tetric® N-Ceram Bulk-Fill, Liechtenstein) was preheated to 39°C for group 1 and 60°C for group 2 in an incubator (Memmert, Germany) for 30 minutes, then taken out and the temperature checked using a digital thermometer. Unpreheated samples were used for group 3. However, temperature checks were still carried out at ambient temperature. The composite was inserted into the mold, then compacted using a cement stopper as soon as possible to avoid a significant temperature reduction after being removed from the incubator. The surface of the composite resin was coated with a Mylar strip and then pressed with an object glass. Polymerization was carried out using a light cure (Woodpecker LED-C, China) for 10 seconds and the distance between the tip unit and the composite was 1 mm (right above the glass object). The sample was released from the mold, then soaked in a plastic jar containing distilled water and stored in an incubator at 37°C for 48 hours. After being kept in the incubator for 48 hours, the jar containing the sample was taken out and dried with tissue paper. A Universal Testing Machine (Controlab/TN20MD, France) was used to evaluate the compression strength of the sample at a pace of 1 mm per minute until it shattered. The amount of compression strength obtained was calculated and documented.

## RESULT

The test results of the compression strength in each group can be seen in Figure 1. Based on the test results in Figure 1, the standard deviation of group 3 indicated poor data distribution due to the existence of values that are too extreme or outliers in group 3. It was necessary to trim the three groups by deleting some outlier data to avoid bias in the analysis results. The trimmed data are presented in Figure 2.

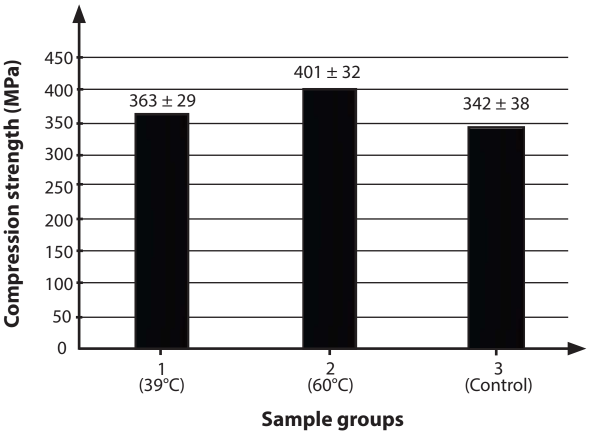


**Figure 1.** Compression strength of sample groups. (Group 1: preheating 39°C, Group 2: preheating 60°C, Group 3: control)

The data in Figure 2 shows that group 1 has an average compression strength result of 367.500 ± 28.97 MPa, group 2 has an average compression strength result of 409.780 ± 24.54 MPa, and group 3 has an average compression strength result amounting to 350.822 ± 30.25 MPa. Based on these results, the compression strength of bulk-fill composite resin in group 2 has the highest average value compared to other groups, and the compression strength of bulk-fill composite resin in group 3 has the lowest average value compared to other groups. The compression strength test results data obtained from the three groups were tested for normality and homogeneity with the results can be seen in Table 1.

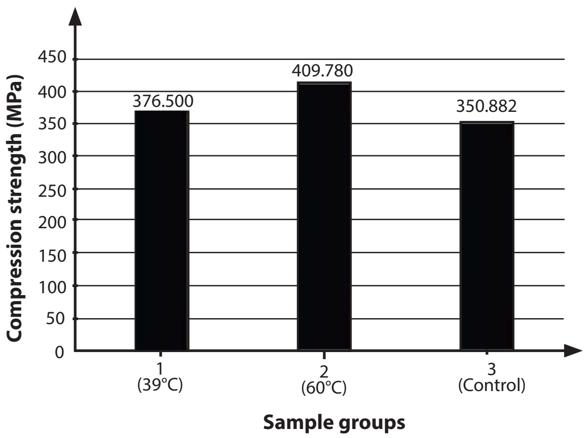


**Figure 2.** Compression strength of sample groups after data trimming. (Group 1: preheating 39°C, Group 2: preheating 60°C, Group 3: control)

Based on Table 1, the compressive data for groups 1, 2 and 3 were normally distributed and homogenous, as indicated by p-value > 0.05. Next, a One-way ANOVA test was carried out with the results shown in Table 2.

**Table 1.** Shapiro-wilk and Levene test results

| Compression strength | | Shapiro-wilk | Levene |
|---|---|---|---|
| **Groups** | **n** | **Sig.** | **Sig.** |
| 1. Preheating 39°C | 8 | 0.200* | 0.690* |
| 2. Preheating 60°C | 8 | 0.736* | |
| 3. Control | 8 | 0.573* | |

**Table 2.** One-way ANOVA results

| Groups | n | Mean ± SD | p-value |
|---|---|---|---|
| 1. Preheating 39°C | 8 | 367.500 ± 28.97 | 0.001* |
| 2. Preheating 60°C | 8 | 409.780 ± 24.54 | |
| 3. Control | 8 | 350.822 ± 30.25 | |

The data in Table 2 shows a significance value of 0.001 (p-value < 0.05). This value shows that there is a significant difference between groups 1, 2, and 3. The data was then carried out by a post-hoc Bonferroni follow-up test, the results of which can be seen in Table 3. Based on Table 3, the results obtained are that there is a non-significant difference between groups 1 and 2 with a value of p-value = 0.020, there is a difference that is not significant between groups 1 and 3 with a value of p-value = 0.742, and there is a significant difference between group 2 and group 3, proven by the value p-value = 0.001 (p-value < 0.05).

**Table 3.** Post-hoc Bonferroni results

| Groups | Compression strength of bulk-fill composite resins | | |
|---|---|---|---|
| | **1** | **2** | **3** |
| 1 | | 0.020 | 0.742 |
| 2 | | | 0.001* |
| 3 | | | |

Group 1: preheating 39°C, Group 2: preheating 60°C, Group 3: control

## DISCUSSION

The results of this study showed that the control group and the 39°C preheating group had lower average compression strengths than the 60°C preheating group. Based on these findings, it is possible to explain why the bulk-fill composite resin's compression strength rises with temperature. This is consistent with studies by Ramadhan (2021), who reported that bulk-fill composite resin's mechanical qualities would rise as the material's degree of polymerization and preheating temperature rise.

According to Tauböck *et al.* (2015), the composite resin's high preheating temperature promotes more optimum polymer synthesis and freer monomer mobility. When compared to composite resin at lower temperatures, composite resin with excellent polymer chain synthesis has a better compression strength (Harahap, 2018). The bulk-fill composite resin's compression strength increased following preheating at a specific temperature, according to the One-way ANOVA test findings, which indicate differences in compression strength among the three groups.

The post-hoc Bonferroni test showed no significant differences between Groups 1 and 2 or between Groups 1 and 3. The possible explanation was the lack of temperature control during preheating, so there were no significant differences in these groups. In contrast to preheating using a composite resin heater, preheating in this study was done in an incubator, which resulted in an unstable decrease or increase in the temperature exposed to the composite resin (Arora *et al*., 2017). Another factor that could affect the data results was that different samples had different diameters. This is due to the mold material was a less durable cylindrical polyurethane, which can lead to inconsistent compression strength calculations for each sample group. Additional findings indicated a substantial difference between the control group and the 60°C preheated group. Based on these data, it can be concluded that preheating at 60°C significantly influences the compression strength of bulk-fill composite resin.

The process of polymerizing composite resin involves a chemical reaction that transforms tiny molecules into long polymer chains. There are various steps in the polymerization process. In the initial stage, visible light from a Visible Light Curing (VLC) units activates polymerization, accelerating resin hardening and allowing for deeper curing (Razibi *et al*., 2017). In order for the coupling agent to effectively bond the resin matrix and filler, VLC light induction takes place throughout the activation process. This causes the activator in the composite resin to react with the photoinitiator in the best possible way. As a result, the links between the elements in the composite resin strengthen, increasing the material's mechanical and physical qualities (Allorerung *et al*., 2015; Shen *et al*., 2021).

The induction stage is the second step in the polymerization process. At this stage, the initiator molecule breaks down into free radicals, and free radical activation takes place. These radicals then combine with the monomer to initiate the polymer chain's synthesis. As the temperature rises, the activation process quickens and stronger polymer cross-links are formed (Harahap, 2018; Shen *et al*., 2021). The propagation stage is the third step in the polymerization process. The ensuing free radicals' approach additional monomers and combine with them to make further free radicals, which quickly produce enormous polymer molecules. This occurs during the propagation phase.

The process of breaking the chain as a result of a radical reaction that creates a covalent single bond is known as the termination stage, which is the fourth stage. Chain transfer is the last step in the polymerization process. The process of moving a radical's reactivity to another molecule so that it can subsequently be reactivated is known as the "chain switching stage" (Shen *et al*., 2021). Increasing the temperature of the composite resin will speed up the polymerization process and produce a more optimal conversion rate compared to composite resin applied at room temperature (Elkaffas *et al*., 2019). An increase in temperature causes the viscosity of the composite resin to decrease so that the monomer will become more flexible to form stronger polymer cross-links. As a result, the density and durability of the composite resin will increase (Harahap, 2018; Poubel *et al*., 2022)

Composite resin polymerization can be influenced by the condition of the patient's oral cavity and by the composition of the composite resin itself (AlShaafi, 2017; Andari *et al*., 2014). This research uses a bulk-fill composite resin, which has a low filler volume and a large filler particle size, thus allowing for increased light transmission to penetrate the resin material (Haugen *et al*., 2020). Bulk-fill composite resin contains a photoinitiator in the form of ivocerin, which can increase the degree of polymerization and depth of cure (Ivoclar, 2014). Based on the statement of Mofidi *et al*. (2020), several bulk-fill composite resins have used technological modifications to reduce stress called polymerization modulators in the form of UDMA content which will interact with the photoinitiator and produce an increase in elastic modulus. This leads to a significant increase in mobility and allows stress to be reduced without reducing the polymerization rate or conversion rate, so that bulk-fill composite resin has higher compressive strength compared to other types of composite resin (Mofidi *et al*., 2020; Van Ende *et al*., 2017).

## CONCLUSION

Preheating at $39^0$C and $60^0$C significantly influences the compressive strength of bulk-fill composite resin. Among the tested groups, preheating at $60^0$C produced the highest compressive strength, exceeding both the $39^0$C group and the control group without preheating. Future research should explore the effect of preheating on various mechanical, physical, and optical characteristics of bulk-fill composite resin. Additionally, assessing different composite materials, long-term aging effects, and in-vivo performance could offer a more thorough insight into how preheating techniques can be effectively tailored for use in clinical settings.

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## AUTHOR CONTRIBUTION

This study was conducted by A. D. N. under the supervision of R. S. and R. B. P., A. D. N. was responsible for the research design, data collection, data analysis, and manuscript drafting. R. S. and R. B. P. contributed through supervision, conceptual guidance, and critical revision of the manuscript. All authors discussed the results and contributed to the final manuscript.

## FUNDING SUPPORT

Not applicable.

## DATA AVAILABILITY

All data generated or analysed during this study are included in this published article. Additional datasets used and/or analysed during the current study are available from the corresponding author upon reasonable request.

## CONFLICT OF INTEREST

The authors state there is no conflict of interest with the parties involved in this study.

## ETHICAL APPROVAL

This study was conducted after receiving ethical approval with reference number 009/KEPK/PE/I/2024 issued on 21st March 2024 by the Health Research Ethics Commission of the Jenderal Soedirman University.

## INFORMED CONSENT

Not applicable.

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