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THE EFFECT OF BEVERAGE TEMPERATURE OF BLACK TEA (*CAMELLIA SINENSIS*) ON THE HARDNESS OF NANOHYBRID COMPOSITE RESIN

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ABSTRACT

Background: Nanohybrid composite resin is a restorative material in the field of dentistry that combines micro and nano-sized filler particles to enhance its mechanical hardness properties compared to its previous versions. Hardness can be influenced by several factors, including patients' beverage consumption patterns. A popular beverage among the Indonesian population is black tea (Camellia sinensis), which can be consumed both cold and hot. **Objective:** This study aims to determine the effect of beverage temperature on the hardness of nanohybrid composite resin. **Methods:** This study is a quasi-experimental laboratory study with a post-test only group design. The research sample consisted of 30 samples of nanohybrid composite resin with a diameter of 10 mm and a thickness of 2 mm, which were divided into three immersion groups: the control group using aquadest solution at 25±1°C, group I using black tea solution at 5±1°C, and group II using black tea solution at 50±1°C. The hardness of the samples was measured using a Vickers Hardness Tester. Data were analyzed using parametric One-Way ANOVA and Post Hoc LSD (Least Significant Difference) test. **Results:** The One-Way ANOVA analysis results showed a significant difference in the hardness values of nanohybrid composite resin after immersion in aquadest at 25±1°C, black tea at 5±1°C, and black tea at 50±1°C with a $p<0.05$. The Post Hoc LSD test results showed significant differences with a $p<0.05$ between the immersion groups. **Conclusion:** There is an effect of beverage temperature on the hardness of nanohybrid composite resin.

BACKGROUND

Dental caries is a disease that affects the structure of tooth tissues, caused by the fermentation resulting from the complex interaction between bacteria on the tooth surface and carbohydrates adhering to it.[1] One approach to treating caries is through restorative procedures using composite resin materials.[2] Composite resins are composed of a resin matrix, filler particles, bonding agents, and an activator-initiator system, which provide advantageous physical, mechanical, and aesthetic properties for dental applications.[3] Composite resins can be classified based on the size of the filler particles, such as macrofilled, microfilled, and nanofilled composites.[4] Advances in dental technology have also led to the development of composite resins combining nano and micro filler particles, known as nanohybrid composites.[5,6] The combination of nano and micro particles is believed to improve the distribution of the filler material within the resin matrix, resulting in enhanced mechanical properties compared to previous composite resins.[7,8]

This improvement does not eliminate the need for further investigation into the impact of various external factors, such as temperature, on the mechanical properties of composite resins, including their hardness. Hardness is a key parameter in determining the durability and success of dental restorations, as higher hardness values enhance a material's ability to withstand masticatory forces and endure long-term in the oral cavity.[9,10] Previous

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studies have indicated that exposure to extreme temperatures can reduce the hardness of composite resin materials.[11] Extreme temperatures refer to the lowest and highest temperatures that the oral cavity can tolerate, namely 5°C and 50°C. Such temperature exposures in the oral cavity may occur through the consumption of everyday beverages, one of which is black tea.[12]

Black tea is a widely consumed beverage in Indonesia, accounting for 78% of the total tea production in 2021.[13,14] Black tea has an acidic pH, which has the potential to affect the mechanical properties of dental restorative materials.[15,16] Produced from the leaves of *Camellia sinensis*, black tea can be consumed at varying temperatures, either as a cold beverage (with temperatures ranging from 1.7°C to 10.9°C) or as a hot beverage (with an optimal temperature of 57.8°C).[11] Therefore, it is essential to investigate how the beverage temperature of black tea, both hot and cold, influences the hardness of nanohybrid composite resin, which is commonly used in dental restorations. This study aims to provide a deeper understanding of the impact of black tea beverage temperature on the hardness properties of nanohybrid composite resin, contributing to the development of more durable and effective dental restorative materials.

METHODS

This study is a quasi-experimental research with a post-test only control group design, using 30 cylindrical nanohybrid composite resin samples (3M Filtek Z250XT) with a diameter of 10 mm and a thickness of 2 mm. The samples were divided into three immersion groups: the control group, using distilled water at 25±1°C; group I, using black tea at 5±1°C; and group II, using black tea at 50±1°C. Each immersion group consisted of 10 samples, determined based on the Federer formula.

The nanohybrid composite resin was placed into a mold, compacted using a cement stopper, and leveled with a cellulose strip matrix before being polymerized with a light curing unit for 20 seconds. Finishing and polishing of the nanohybrid composite resin were performed using Sof-Lex discs according to the manufacturer's instructions. Afterward, the nanohybrid composite resin was removed from the mold and immersed in artificial saliva in an incubator at 37°C for 24 hours.

The black tea immersion solution was prepared by boiling 4 tea bags, each weighing 2 grams, in 800 ml of water at 100°C for 4 minutes. The black tea solution was then filtered and divided into two beakers labeled PI (Group I) and PII (Group II). The solution for Group I was left to cool to room temperature and then stored in the refrigerator to reach a beverage temperature of 5±1°C. The solution for Group II was cooled to a beverage temperature of 50±1°C and placed on a hotplate stirrer to maintain a stable temperature. After incubation, the samples were washed, dried, and then placed into their respective immersion groups: the control group in the chiller, Group I in the freezer, and Group II on the hotplate stirrer. The immersion process was carried out in 56 cycles, each cycle consisting of 10 minutes of immersion, a 10-second rinse with distilled water, and 10 minutes of further immersion. The total duration of this immersion protocol was designed to simulate the use of restorations over a period equivalent to 112 days, or approximately 4 months of restoration use, based on the assumption that patients consume tea for about 10 minutes per serving.

After the immersion process, the hardness of the samples was tested using a Vickers Hardness Tester with a 100 gf load applied at three surface points for 15 seconds. The indentation area was calculated using the VHN formula and averaged to determine the hardness of the nanohybrid composite resin. The data obtained were analyzed using the Shapiro-Wilk normality test. After confirming that the data met the normality assumption, further analysis was performed using One-Way ANOVA to compare the hardness differences among the immersion groups, followed by a Post Hoc LSD (Least Significant Difference) test to identify which groups were significantly different. All statistical analyses were performed using SPSS version 25.

RESULTS

Table I shows differences in the average hardness of nanohybrid composite resin samples immersed in distilled water at 25±1°C, black tea at 5±1°C, and black tea at 50±1°C.

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Table 1. Mean and Standard Deviation (SD) of nanohybrid composite resin hardness

Group	Mean ± SD (VHN)
Control	104,0± 1,84875
Group 1	97,1± 1,54161
Group 2	90,8± 2,3843

* Normality test P> 0,05; significant

Based on table 1, the highest average hardness value was observed in the control group (distilled water at 25±1°C), followed by group I (black tea at 5±1°C), with the lowest value found in group II (black tea at 50±1°C).

The data analysis was further conducted using a One-Way ANOVA test to determine the differences in the hardness of nanohybrid composite resin. The results of the test are presented in Table 2.

Table 2. One way ANOVA result

	Sum of Squares	df	Mean Square	f	p-value
Between Groups	881,006	2	440,503	115,121	0,000*

*One Way ANOVA P> 0,05; significant

Based on the results of the One-Way ANOVA test, a p-value of 0.000 was found, indicating a significant difference in the hardness values of nanohybrid composite resin after immersion in distilled water at 25±1°C, black tea at 5±1°C, and black tea at 50±1°C. A Post Hoc LSD (Least Significant Difference) test was then conducted to identify specific differences between the treatment groups. The results of the Post Hoc LSD test are presented in Table 3.

Table 3. Post hoc LSD test result

Group	Control	Group I	Group II
Control	-	0,000*	0,000*
Group 1	0,000*	-	0,000*
Group 2	0,000*	0,000*	-

*Post Hoc LSD P> 0,05; significant

The results of the Post Hoc LSD test indicate a significant difference with a p-value of <0.05 between the groups, suggesting that each group has a significantly different hardness level.

DISCUSSION

The results of this study demonstrate significant differences in the hardness of nanohybrid composite resin after immersion in different solutions. The control group (distilled water at 25±1°C) exhibited the highest average hardness, while the groups immersed in black tea at 5±1°C and 50±1°C showed a progressive decrease in hardness. These findings are consistent with the results of Puspitasari et al., who reported a decrease in composite resin hardness following thermal cycling procedures with exposure to extreme temperatures, indicating the sensitivity of restorations to temperature fluctuations in the oral cavity.[11]

According to Rasha et al., cold beverages with temperatures ranging from 5ºC to 7ºC cause variations in the thermal expansion coefficients of composite resin components. Drastic temperature changes with high intensity can trigger a reduction in the hardness of composite resin materials and gradually lead to the formation of microcracks.[17] Similarly, Tuncer et al. found that exposure to high temperatures, particularly above 50ºC, can also result in a decrease in the hardness of nanohybrid composite resin.[18] This can be explained by the thermal stress caused by the cumulative effects of prolonged shrinkage and expansion of the composite resin material. Additionally, higher temperatures increase water absorption, solubility, and diffusion coefficients in composite resin, which in turn affects the hardness of nanohybrid composite resin.[19]

In this study, the temperature of the distilled water solution, 25 ± 1°C, was considered a safe temperature for the consumption of food and beverages. According to Mousa et al., the consumption of food and beverages at room temperature within the range of 20°C to 25°C does not significantly alter the temperature of the oral cavity.[20] Islami et al. stated that the optimal temperature range acceptable to human oral tissues is between 5°C and 50°C.[12]

Exposure to temperature in the oral cavity can occur through various means, such as the consumption of black tea at varying beverage temperatures. At high temperatures, the tannin content in black tea is fully extracted, leading to an increase in the concentration of H^+ ions in the solution.[21] Nanohybrid composite resins have a significant drawback, which is their high hygroscopicity due to the presence of hydroxyl

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groups in the resin matrix molecules.[22] The H^+ ions in black tea can diffuse through the resin matrix by binding to its hydrophilic groups. These absorbed H^+ ions exist in two forms: unbound H^+ ions occupying free spaces between polymer chains, and bound H^+ ions attaching to polymer chains via hydrogen bonds. The high concentration of H^+ ions trapped within the resin matrix can trigger the disintegration of the resin matrix structure, causing structural damage and resulting in a reduction in its hardness.[22,23]

Although this study focuses on the effects of black tea, previous research has also shown that other acidic beverages, such as coffee, fruit juices, and carbonated drinks, can similarly affect the mechanical properties of composite resins. A limitation of this study is that it exclusively tested the hardness of composite resins, and further studies are needed to investigate the effects of beverage temperature on surface roughness and color changes in composite resins, in order to provide more comprehensive information.

The findings of this study have important clinical implications for dental practitioners, as they may influence recommendations for post-restorative care. Patients with composite restorations, particularly those made from nanohybrid composite resins, may benefit from avoiding extreme beverage temperatures to preserve the integrity and longevity of their restorations.

CONCLUSION

There is an effect of black tea beverage temperature on the hardness of nanohybrid composite resin, with a greater reduction in hardness observed in resin samples immersed in black tea at 50±1°C compared to those immersed in black tea at 5±1°C.

ETHICAL APPROVAL

The study received ethical approval from the Health Research Ethics Committee of the Faculty of Medicine, Diponegoro University, Semarang (No. 150/EC-H/KEPK/FK-UNDIP/XII/2023).

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest in this study.

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AUTHOR CONTRIBUTIONS

Conceptualization: GRH, MM; Methodology: GRH, MM, NH; Data analysis: GRH; Data collection: GRH; Source of funds: GRH; Writing the original draft: GRH; Review and edit: GRH, MM, NH; Supervision: MM, NH.

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