Effects of Chili Sauce on the Absorbency and Diametral Tensile Strength of Nanocomposite

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Effects of Chili Sauce on the Absorbency and Diametral Tensile Strength of Nanocomposite

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***Abstract*—Absorbency and solubility of nanofilled resin composite (nanocomposite) affect its strength and durability. Furthermore, exposure to acids in the oral cavity such as chili sauce also reduces the mechanical and physical properties of composite resin restoration. Therefore, this study aims to evaluate the effect of chili sauce on nanocomposite absorbency and diametral tensile strength. Thirty-three nanocomposite samples in cylindrical shape were divided into 3 groups (n=11); immediate control (1), control (2) immersed for 24 hours in distilled water and treated (3) soaked for 8 hours in distilled water and 16 hours in chili sauce solution. All samples were immersed for 4 days in a 37^{0}C incubator. Absorbency was measured according to the difference of weight before and after immersion, while the diametral tensile strength was measured using Universal Testing Machine. There was a significant difference ($p<0.05$) in diametral tensile strength among groups; group 1 and 3 were stronger than group 2 by 10.8% and 13.4%, group 1 was not significantly (1.2%) weaker than group 3. No significant difference was found ($p>0.05$) in the absorbency test, although group 3 is 16% higher than group 2. Therefore, chili sauce affects the diametral tensile strength of nanocomposite significantly, but not its absorbency.**

Keywords*—nanocomposite, chili sauce, absorbency, diametral tensile strength

I. Introduction

Dental caries is one of the most common human diseases [1] and is a pathological process that is caused by several etiological factors which leads to tissue damage in the oral cavity [2]. When the carbohydrates, that is fermented by *Streptococcus mutans,* are exposed to the oral cavity, lactic acid is formed by *Lactobacillus* which lowers the oral cavity pH and triggers demineralization. Therefore, when this process continuously occurs without remineralization, it leads to caries formation [3] [4].

As stated in 2018 Basic Health Research *(Riset Kesehatan Dasar)* [5], most Indonesians have dental cavity problems, with an average caries prevalence of approximately 88.8% [6]. One of several ways to restore a carious lesion is by using dental filling material such as composite resin, which has become popular recently due to its good strength and high aesthetic value as tooth-colored restoration [7].

The composition of composite resin consists of matrix, inorganic filler, and coupling agent. Based on the particle size of the filler, composite resins are divided into macrofilled, microfilled, hybrid, microhybrid, and nanofilled. The nanocomposite, also known as nanofilled resin composite, has the smallest and finest filler size in the range of 5-100 nm [8][9]. This material, which is developed using nanotechnology, has better physical properties than others, especially its polishing result and strength. Meanwhile, fillers in nanocomposite combine individual nanoparticles and nanocluster particles that are easily bond each other to form groups. This combination improves its physical properties and gives better polishing results compared to other composite resins. Furthermore, the nanocomposite becomes non-sticky which makes it easier for dentists to manipulate [10].

Despite all these advantages, nanocomposites are easily degraded by acids due to some unstable bonds in their polymer. Similarly, the absorption of acidic materials causes the composite resin to undergo polymer and filler degradation which softens its biomaterial and causes a reduction in its mechanical and physical properties [11]. A previous study conducted by Borges et al. [12], stated that exposure to acidic substances reduces the diametral tensile strength of composite resin.

Food is one of the etiological factors causing caries and is also a basic human need [2]. For most Indonesians, chili sauce consumption as a food additive is widespread. This sauce contains chilies *(Capsicum, sp.)*, sugar, salt, vinegar, garlic *(Allium sativum L.)*, water, monosodium glutamate (MSG), and sodium benzoate as preservatives. These ingredients function in assembling the sauce's texture, taste, color, and durability.

Chili contains capsaicin and pungency that has antimicrobial properties and vitamin C, which keep the gums and oral tissue healthy [13]. Similarly, garlic also has antimicrobial properties that are contained in its allicin [14]. Meanwhile, sugar has an important role in caries formation which affects restoration's durability and leads to secondary caries [2]. The vinegar makes chili sauce acidic which degrade the surface and lead to microleakage of restoration and reduces its physical and mechanical properties [11]. One of the quality requirements of chili sauce, based on the Indonesian National Standard (INS) or *Standar Nasional Indonesia (SNI)* [15], is to have a maximum pH of 4 which is a critical value for caries formation. Therefore, chili sauce is assumed to have an antimicrobial effect that causes dental cavities and affects the physical and mechanical properties of restoration. Previous studies evaluated composite resin's mechanical and physical properties after immersed in acidic solution [16], mouth rinse [17], hydrogen peroxide [18], ethanol and anthocyanin pigment [19], also water absorbency which indicates its capability to absorb any fluids that cause discoloration [20]. Therefore, this study aims to examine the effect of chili sauce on the absorbency and diametral tensile strength of nanocomposites restorative material, which has not been examined in previous studies.

II. Research Methodology

This experimental laboratory study was conducted at the Dental Materials and Testing Center of Research (DMT Core) Laboratory in the Faculty of Dentistry, Universitas Trisakti, Jakarta, Indonesia.

A. Materials

The materials used include Filtek™ Z350 XT nanocomposite (shade A2, LOT NA79689, 3M ESPE, USA), Dua Belibis chili sauce (LOT 256331082017, PT. Anggana Catur, Indonesia), and distilled water (Klin's Laboratory, Indonesia).

B. Samples

The samples in this study were 33 cylindrical nanocomposites made in stainless steel molds with a diameter of 6 ± 0.1 mm and a height of 3 ± 0.1 mm. The number of samples was determined by the Lemeshow formula [21], which leads to 11 samples for each group. The formula is as follows:

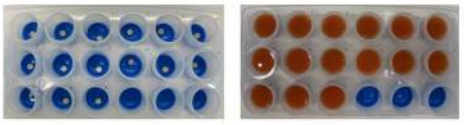
$$n = \left(\frac{(Z\alpha + Z\beta)S}{x_1 - x_2}\right)^2 \quad (1)$$

with n is total of samples, Zα is alpha standard deviation (1.96), Zβ is beta standard deviation (0.84), S is standard deviation (0.026), and $(x_1 - x_2)$ is minimum significant mean difference.

Polymerization was carried out after the sample was coated with a celluloid strip using a light-curing unit for 2 x 20 seconds at the top of the mold. The curing distance was set at approximately 1 mm between the tip of the unit and the composite, and the beam direction was placed perpendicularly to the sample. After setting, the sample was removed from the mold and ensured that the surface is smooth, even, without porosity and fracture lines based on the American Dental Association (ADA) Specification No. 27 [22].

C. Methods

Immediately after manufacture, all samples were measured using a caliper and weighed on an analytical balance, before being tested for diametral tensile strength. Each sample was measured 3 times and averaged into a single value. The 11 control samples (group 1) were immediately tested for diametral tensile strength, while group 2 samples were immersed in distilled water and stored in an incubator (37°C) for 4 x 24 hours. Furthermore, as shown in Fig. 1, the 11 treated samples (group 3) were immersed in distilled water for 8 hours and continued in chili sauce solution for 16 hours and were repeated for 4 days in an incubator (37°C) [16]. The overall steps taken in this study are shown in Fig. 2.



(a) (b)

Fig. 1. Nanocomposite's immersion in: (a) distilled water), (b) chili sauce solution

Before changing solution, all samples were cleaned and rinsed with distilled water for 10 seconds. Meanwhile, the solution was made by mixing chili sauce into distilled water with a ratio of 1:1 (Fig. 3) and was measured (Fig. 4). After the immersion, a total of 22 samples (groups 2 and 3) were tested for absorbency and diametral tensile strength (Fig. 5).

A total of 22 control and treated samples were weighed after completion of immersion to test their absorbency, which was calculated using the following equation [23]:

$$M_t(\%) = \frac{mt - m_0}{m_0} \, x \, 100 \quad (2)$$

with M_t is absorbency (%), mt is mass after immersion (g), and m_0 is mass before immersion (g).

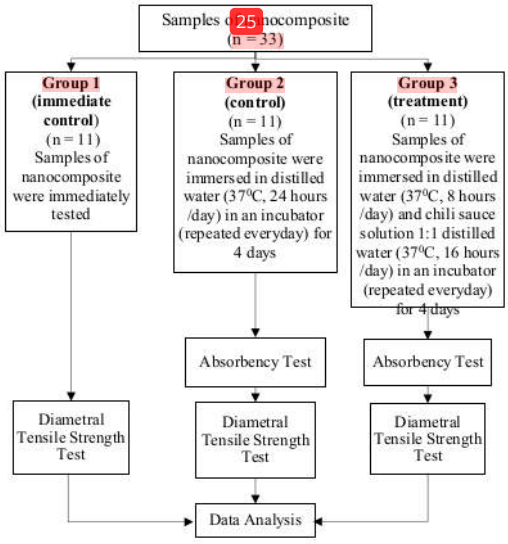


Fig. 2. Research steps

Fig. 3. Chili sauce solution (chili sauce : distilled water is 1:1)

(a) (b)

Fig. 4. Measurement of pH: (a) chili sauce solution, (b) distilled water

D. Data Analysis

The data obtained were tested for normality with the Shapiro-Wilk and homogeneity with Levene's test. Furthermore, the data were analyzed using an independent t-test on the absorbency while the diametral tensile strength was conducted using the ANOVA statistical test. Since there was

a significant difference, the analysis was continued with the post hoc Tukey test. All data were tested using SPSS 23.

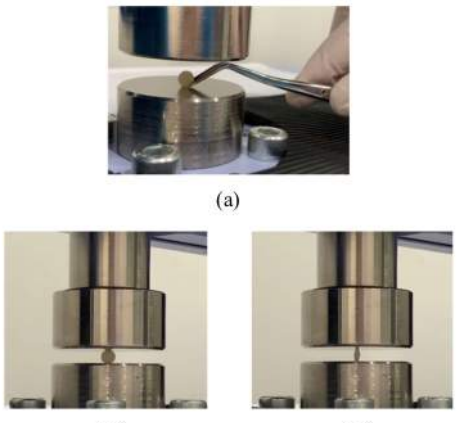


Fig. 5. Diametral tensile strength test using a Universal Testing Machine: (a) placing sample with cotton pliers, (b) sample position, (c) result

III. Result and Discussion

The pH value of distilled water and chili sauce solution in ratio 1:1 was measured using a pH meter. The chili sauce solution was 4.0, while the distilled water was 6.6.

A. Absorbency

Absorbency is the ability of a material or an object to absorb liquids. The absorption of acidic materials leads to the degradation and softening of the composite resin, so that the mechanical properties such as surface roughness, tensile strength, wear resistance, and others are reduced.

TABLE I. Absorbency Data Results

Sample	Group 2 (Control)		Group 3 (Treated)	
	Absorbency (%)	*Absorbtion (µg/mm³)*	*Absorbency (%)*	*Absorbtion (µg/mm³)*
1	0.51	10.5	0.67	12.7
2	0.23	4.6	0.73	13.8
3	0.76	15.0	0.64	12.8
4	0.81	16.1	0.48	9.4
5	0.69	13.6	0.47	9.3
6	0.30	5.8	0.52	10.3
7	0.77	15.2	0.29	5.8
8	0.34	7.0	0.36	7.2
9	0.31	6.0	0.47	9.3
10	0.41	8.1	0.41	8.1
11	0.42	8.1	0.35	6.9
Mean	0.50 ± 0.22	10.0	0.49 ± 0.14	8.4

The absorbency differences of the control group and treated group was measured by weighing the samples before and after immersion using an analytical balance and were calculated using the mass gain percentage formula. Meanwhile, the test was not conducted in the immediate control group, which was directly tested for diametral tensile strength after manufacturing without immersion. The average value of the absorbency is shown in Table I. Levene's and Shapiro-Wilk's methods were used to test the homogeneity and normality data ($n \leq 50$). The significant value (p) of the homogeneity test was 0.200 and normality test for nanocomposites absorbency was 0.224 for group 2 and 0.614 for group 3. Both were $p \geq 0.05$, which showed that the data were homogenous and normally distributed. Furthermore, data were analyzed using an independent t-test to determine the difference in the average of groups 2 and 3, which showed that the absorbency test between the two groups was not significantly different ($p \geq 0.05$) with the value of $p = 0.844$, yet the value of treated group (8.4 µg/mm³) is 16% less in comparison with the control group (10.0 µg/mm³).

B. Diametral Tensile Strength

Diametral tensile strength test is an indirect measurement used to measure the strength of brittle materials by applying a perpendicular pressure which makes the material become loose and eventually break. These samples were tested using Universal Testing Machine with a crosshead speed of 1 mm /minute until the sample broke. The result of diametral tensile strength is shown in Table II.

TABLE II. Data and Statistical Test of Diametral Tensile Strength

Diametral Tensile Strength (MPa)			
Sample	*Group 1 (Immediate)*	*Group 2 (Control)*	*Group 3 (Treated)*
1	46.97	33.83	46.03
2	46.03	33.92	42.50
3	54.96	43.97	49.60
4	44.13	44.68	47.47
5	54.28	39.00	51.50
6	45.19	37.67	42.88
7	45.48	47.03	50.82
8	42.50	46.38	39.35
9	42.43	39.13	49.60
10	41.63	42.25	38.33
11	50.19	35.01	47.53
Mean	45.44 ± 4.72^{a}	40.55 ± 5.09^{b}	45.98 ± 4.59^{a}

[a,b] Different alphabet shows significant difference with Tukey test ($p < 0.05$)

Data obtained in this study were analysed using Levene's test for homogeneity and Shapiro-Wilk for normality which showed all the data were homogenous and normally distributed ($p \geq 0.05$). The reliability data was also good with the coefficient of variance in group 1 was 10.4%, group 2 was 12.6%, and group 3 was 10%. Therefore, analysis was continued with a one-way ANOVA statistical test which showed significant difference ($p < 0.05$) among groups. Then, the data analysis was continued using post hoc Tukey test with significance value (p) of group 1 towards 2 was 0.019, while group 2 towards 3 was 0.033. This showed that there was significant difference ($p < 0.05$) in group 2 towards group 1 and 3.

After immersion in distilled water for 4x24 hours, the diametral tensile strength of nanocomposite samples were reduced by 5.90 MPa. On the contrary, the value of chilli sauce treated nanocomposite samples was not significantly different in comparison with immediate samples.

C. Analysis

Different environmental exposures such as humidity, water, chemicals, and acids cause changes in the nanocomposite matrix polymer's microstructure and chemical composition, which affect its mechanical and physical properties. In this study, methods used for determining the physical and mechanical properties of restorative material are absorbency and diametral tensile strength tests.

Group 1 was conducted as a comparison for groups 2 and 3. This group was used as the control without treatment; therefore, it was taken as the pre-test value. Meanwhile, group 2 was the comparison after 24 hours of immersion in distilled water (pH 6.6). The chili sauce was dissolved 1:1 in distilled water in group 3 (pH 4) to adjust the actual conditions of the oral cavity. Assuming a person eats chili sauce daily and being exposed for 5 minutes per day, 16 hours immersion of nanocomposite samples in chili sauce solution for 4 days is equivalent to 2 years, 1 month, and 18 days (25.6 months) in vivo.

Based on ISO 4049, the maximum absorption value of polymer-based restorations is 40 $\mu g/mm^3$ [24]. Therefore, the average result of absorption values in group 2 (10.0 $\mu g/mm^3$) and group 3 (8.4 $\mu g/mm^3$) were lower than the standard maximum absorption value for polymer-based restorations. The average absorbency result of group 3 was lower than group 2, which was affected by the water content and molecule size of chili sauce solution. Chili sauce has a higher viscosity than distilled water, which makes it harder for the sauce molecules to enter the polymer chain and more difficult to absorb. Despite the values differences, after an independent t-test, the absorbency value between the two groups was not significantly different. This condition occurs because the Filtek™ Z350 XT nanocomposite filler is densely filled and has a good bond with the matrix so the space and pathways for water molecules to diffuse in the polymer structure are very limited.

In the diametral tensile strength test, the final values of the three groups as shown in Table II are within the normal average 30-55 MPa [25]. The post hoc Tukey test showed th was significant differences of 10.8% in group 2 towards 1, while there w no significant difference in group 3 towards 1 even though group 3 was hig than group 1. The value of group 3 is 13.4% significantly higher than group 2.

The value of group 3, which is higher than group 2 in the diametral tensile strength test, is assumed due to the content of calcium from chili and garlic in the sauce [26] [27]. When the composite is exposed to chili sauce with an acidic pH of 4.0, surface degradation occurs and the Ca^{2+} ions contained in the chili sauce solution enter the composite. Furthermore, when the sample is immersed in distilled water, a layer is formed and covered the surface of the composite to finally neutralizes the pH and stops the corrosive action. The free ion of Ca^{2+} is one of the factors that strengthen the composite to reduce microcracking issues [28].

Although it is assumed that higher absorbency will decrease diametral tensile strength, in this study it is quite interesting that the three highest absorbency values in group 2 (samples no. 3, 4, and 7) and 3 (samples no. 1, 2, and 3) do not show the lowest diametral tensile strength values. This exact inverted condition is also showed in group 2 (samples 2, 6, and 9) and group 3 (samples no. 7, 8, and 11) which shows the lowest value in absorbency but do not show the highest diametral tensile strength values. Porosity is not one of the issues for these phenomena since internal porosity will result in higher absorbency and lower diametral tensile strength. There must be other reasons e.g., composition of nanofiller or hydrophilicity of resin matrix, that may cause these phenomena and should be evaluated in further study.

Despite all the possible reasons and phenomena, nanocomposite group that is immersed in chilli sauce shows less absorbency and consequently stronger diametral tensile strength in comparison with group that is immersed in distilled water. Moderate consumption of chili sauce does not give harmful effect towards the diametral tensile strength of nanocomposites. However, people are advised not to consume this food excessively, due to the presence of preservatives, MSG, and sugar in chili sauce which causes various diseases. Drinking or rinsing with water and brushing teeth after consuming chili sauce are suggested, to prevent discoloration of the composite resin restoration as shown in Fig. 6.

(a) (b)

Fig. 6. Nanocomposite sample: (a) before immersion, (b) after immersion in chili sauce for 4 days

The staining susceptibility of composite resins is attributed to their degree of water sorption and hydrophilicity of the resin matrix. Clinically composite color stability depends upon factors such as the type of cavity design, etching and bonding procedures, degree of conversion, surface roughness, and thermal stresses, which are not analyzed in this study. Therefore, further study on the side effects of food colorant from chili sauce is recommended.

IV. Conclusion

In comparison with the immersion in distilled water, immersion in chili sauce inc es nanocomposite's diametral tensile strength by 13.4%. However, there is no significant difference ($p \geq 0.05$) in its absorbency after 4x24 hours of immersion. Therefore, immersion of the nanocomposite in chili sauce is not worse than in distilled water.

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