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The Effects of Thickness Changes in Different Composites on Translucency, Opalescence, and Masking Efficacy

Beyza Unalan Degirmenci[1]✉, Alperen Degirmenci[2]

Objective: **The aim of this study is to evaluate the effects of thickness increase in nanohybrid and microhybrid composites on translucency, opalescence and masking efficacy.** ***Material and methods:*** **For this study, a total of 72 composite discs with thicknesses of 1, 1.5 and 2 mm were prepared from nanohybrid and microhybrid composites. Disk measurements were made with the aid of a spectrophotometer and translucency parameter (TP), opalescence (OP-BW) and masking efficacy (ME) were calculated.** ***Results:*** **The decrease in the values of TP and OP-BW and increase in the values of ME were observed with thickness increase in both microhybrid and nanohybrid composites. Moreover, while statistically significant positive correlation was detected between TP and OP-BW, it was also detected that ME and TP and ME and OP-BW were statistically significant between each other but negative correlation was detected.** ***Discussion:*** **The thickness of composite materials directly affects the aesthetic properties of restorative materials.**

INTRODUCTION

The demands on the aesthetic restoration of anterior teeth of patients are increasingly increasing. As the result of these demands, different treatment options are offered to patients by assessing dentition status. The enamel and dentine-bonding capacities of the restorative materials used in these options have shown a significant improvement with the introduction of multi-step total-etch adhesive systems to the market (1). However, for the aesthetic success of restorations it is necessary that they have a similar color and shape with adjacent teeth, and that they exhibit a certain harmony with them (2). The aesthetic success of restorative materials is affected by various factors including optical characteristics such as color, translucency, opalescence, metamerism and fluorescence, and surface roughness, polish and restoration size (3). Translucency is the ability of a material to pass the light through. Translucency can also be described as a condition between full opacity or transparency (4). Apart from material thickness, the translucency of composite resins depends on the coefficient of resin scattering and absorption, the type of filler particles, and on the coloring agent and opacifiers the material contains (5-7). Opalescence occurs when a light in the visible spectrum is scattered on the material, and depending on this condition, when the reflected light appears in bluish and the transmitted light appears in an orange/brown color (8). The value of translucency or opalescence of a material can be measured by a variety of methods. These methods can include visual or digital measurements (9). In many studies measuring transluscence or opalescence of the material, translucency was determined by measuring the color of the material in uniform thickness in black and white backgrounds and by calculating the color difference (10, 11). Translucency is usually determined by the contrast ratio (CR) or translucency parameter (TP). CR is defined as the ratio of the amount of reflected light (Yb) from the object over black background (black-B) and amount of reflected light from the object over white background (White-W) (12). Whereas TP value indicates the color difference between black and white backgrounds of a material in certain thickness (13).

The masking efficacy (ME) is a description used to compare the ability of composite resins to mask existing discolorations at the lower background. The masking efficacy is clinically indicates the opposite of translucency. Researchers have revealed that underlying stains could be seen with the use of restorative materials with translucency similar to the natural tooth for anterior restorations, thereby defining the characteristics of masking of a restorative material was recorded into literature (14-16). This is why before using a composite, the translucency of which is similar to enamel, the use of more opaque composites is recommended to mask a colored tooth tissue (17-19).

The aim of this study is to investigate the changes of translucency, opalescence and masking efficacy occurred in the composites as the result of changes in the thicknesses of nanohybrid and microhybrid composites which are frequently preferred in construction of a composite laminate.

[1]Assistant Professor, Van Yuzuncu Yil University, Faculty of Dentistry, Department of Prosthodontics, Van, Turkey Tel: 05066272945, E-mail: beyzaunalan@yyu.edu.tr; [2]Assistant Professor, Van Yuzuncu Yil University, Faculty of Dentistry, Department of Restorative Dentistry, Van, Turkey Tel: 05301819985, E-mail: adegirmenci@yyu.edu.tr

✉*Corresponding Address:*Beyza Unalan Degirmenci, Van Yuzuncu Yil University, Faculty of Dentistry, Department of Prosthodontics, Van, Turkey, Tel: 05066272945, E-mail: beyzaunalan@yyu.edu.tr

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MATERIALS AND METHODS

Two composites were used for our study: a microhybrid (G-ænial Anterior A2, GC Corporation, Tokyo, Japan) and a nanohybrid (Clearfil Majesty ™ ES-2 A2, Kuraray Noritake Dental INC. Okuyama, Japan). Discs with thicknesses of 1, 1.5 and 2 mm and with diameter of 12 mm were prepared from these composites. A sampler (Smile Line, Saint-Imier, Switzerland), a composite mold of stainless steel, the depth of which can be adjusted according to needs, was used during preparation of discs. The composite resin was placed into the sampler by using a spatula and following the placement of cement glass it was polymerized with the aid of the LED light device (3M ESPE Elipar FreeLight 2 LED Light Device, St. Paul, USA) for 20 seconds.

The groups were determined as follows:
Group 1: nanohybrid composite with thickness of 1 mm
Group 2: nanohybrid composite with thickness of 1.5 mm
Group 3: nanohybrid composite with thickness of 2 mm
Group 4: microhybrid composite with thickness of 1 mm
Group 5: microhybrid composite with thickness of 1.5 mm
Group 6: microhybrid composite with thickness of 2 mm

A total of 72 samples were prepared so as 12 samples were included in each study group. The obtained sample surfaces were rubbed for standardization with the 800, 1000 and 1200-grit water sandpapers for 10 seconds by a single operator and immersed in distilled water (Memmert UN 110, Schwabach, Germany) at 37 ° C for 24 hours in the incubator. In the calculation of translucency values after a 24-hour period, the obtained values of L, a and b measured by spectrophotometer so as the samples to be on the black and white backgrounds were calculated by the following formula: $TP=[(LB^*-LW^*)^2 + (aB^*-aW^*)^2 +(bB^*-bW^*)^2]^{1/2}$.

When it comes to opalescence values (OP-BW), the values of samples in white (L *: 96.6, a *: - 1.2, b *: 3.8) and black (L *: 2.4, a *: 1.7 b *: - 1.9) backgrounds were measured (Figure 1, 2) with the spectrophotometer (Spectroshade Micro, MHT Optic Research, Verona, Italy). Afterwards, the opalescence value of the related sample was calculated using the following formula: $OP\text{-}BW=[(CIE\ aB^*-CIE\ aW^*)^2 +(CIE\ bB^*-CIE\ bW^*)^2]^{1/2}$.

The masking efficacy (ME) of the composites was calculated by measuring the values of a and b of the black background, and by measuring a and b values of the related sample in the black background.

RESULTS

The detection of differences between the groups and the statistical analysis of the obtained results was performed with SAS 9.4 software (SAS Institute Inc., 100 SAS Campus Drive, Cary, NC, USA).

The descriptive statistics (mean, standard deviation, minimum and maximum values) were used to describe features of the data collected in the study. Differences between the study groups were assessed using the one-way analysis of variance (One Way ANOVA). The significance level (p) is considered to be 0.5 or less. Whether the normal distribution assumption of the groups was achieved or not was checked by the Shapiro-Wilk test. Another important assumption of the analysis of variance is the homogeneity of the variances of the groups which was checked by using Levene's homogeneity test. Multiple comparison tests were performed with Duncan test to groups in which significant differences were found as a result of the analysis of variance. Pearson correlation coefficients were calculated to determine the relation between variables and they were presented with statistical significance levels.

The results of the one-way ANOVA and descriptive statistics among the groups for the translucency parameters are shown in Table 2.All groups showed the normal distribution assumption in the Shaphiro-Wilk test. Furthermore, by using the Levene's Test, it was determined that the variance of the groups was homogeneous. According to results of the one-way ANOVA, the difference between the mean values of the groups was found to be statistically very significant ($p < 0.0001$). The highest TP value was observed in the 4th group (microhybrid composite with thickness of 1 mm) as 26,87, while the lowest TP value was observed in the 3rd group (nanohybrid composite with thickness of 2 mm) as 17,14.

The results of the one-way ANOVA among the groups of OP-BW index used for the opalescence values of the samples and the descriptive statistics of the groups are given in Table 3. According to the Shaphiro-Wilk test results, normal distribution assumption of the groups was obtained. Furthermore, by using the Levene's Test it was determined that the variances of the groups were homogeneous. According to results of the one-way ANOVA, the difference between the mean values of the groups was found to be statistically very significant ($p<0.0001$). The highest mean value in terms of OP-BW index was detected in the 1st group and it was found that it was statistically different from the other groups. In addition, groups 2, 4 and 5 were found to be statistically similar.

The descriptive statistics for the ME index measured for the masking efficacy and the results of the one-way ANOVA are shown in Table 4. The highest mean value of the ME index was found to be in the group 6. And it is followed by the group 3 and group 5 respectively and there is no statistical difference between these two groups ($p> 0.0001$). The lowest value was observed in the group 1 and statistically it was found to be different from all groups ($p <0.0001$).

The Pearson correlation test results and the statistical significance level coefficients of OP-BW, TP and ME variables are given in Table 5. According to Pearson correlation test results, a positive correlation (86%) was detected between OP-BW and TP and it was found to be statistically significant ($p <0.0001$). According to this correlation, it can be stated that OP-BW and TP show together a strong and significant increase. Meanwhile, a negative correlation (67.90%) was found between OP-BW and ME variables. This high and negative correlation was found to be statistically significant ($p <0.0001$). While this correlation shows that the OP-BW variable increases, when it comes to the ME value, the correlation indicates that it tends to decrease. A correlation as -72,81% was found between TP and ME variables. This correlation, which is negative, high and statistically significant ($p <0.0001$), indicates that the decreases in the ME index occurred due to the increase in TP are meaningful.

DISCUSSION

The translucency parameter was first obtained by direct measurement based on the color change of maxillofacial elastomeric materials in a certain thickness (13). Being originated from the CIELAB color space (7) has become the most commonly preferred parameter by researchers in TP translucency measurements since it is calculated with a formulation similar to color change formulation (20), and it is revealed that it produces a mathematical result supporting the clinical observations of the conducted studies (7, 20-22). Although there are different translucency measurement formulations such as Contrast Ratio (CR), the TP formulation was used to calculate the translucency changes in our study, taking into consideration all these literature data.

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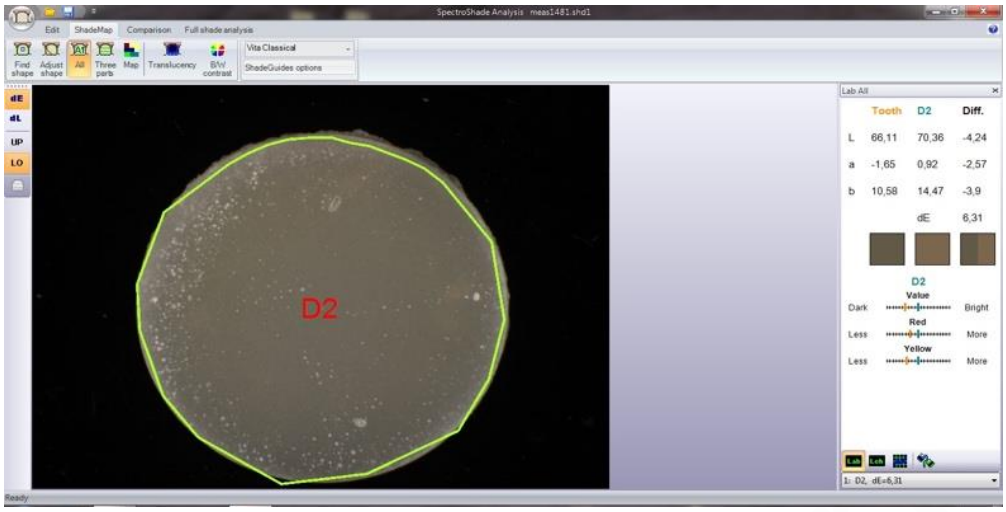

Figure 1 Spectrophotometric measurement at black background

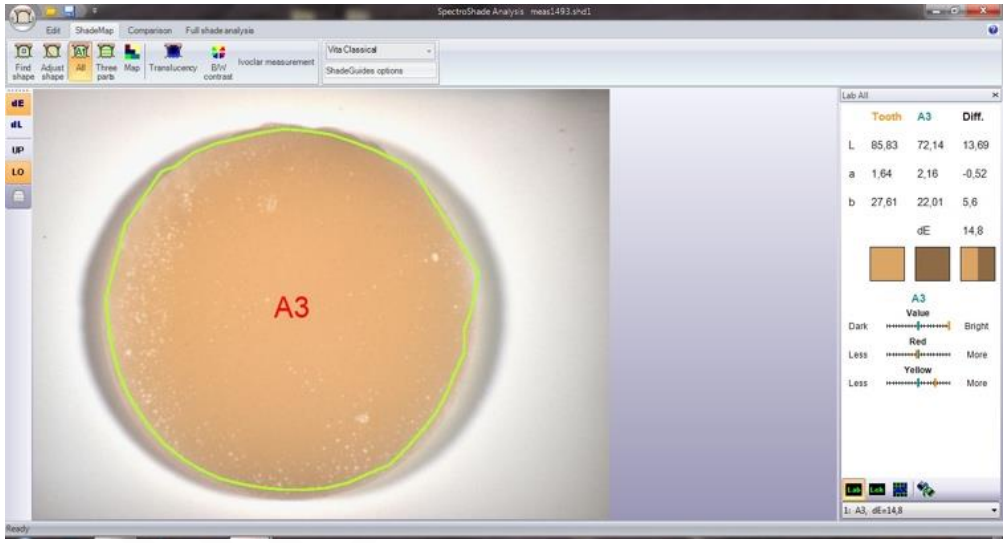

Figure 2 Spectrophotometric measurement at white background

Table 1 Composite resins and specialites which were used in our study

Composite Brand	Manufacturer	Type	Ingredient of inorganic filler	Filler ratio and size	Resin/Matrix
Clearfil Majesty™ ES-2	Kuraray Noritake Dental INC. Okuyama, Japan	Nanohybrid	Silanized barium glass filler, pre-polymerised organic filler	Weight %78, Volume % 40, 0,37-1,5 µm	Bis-GMA, Hydrophobic aromatic dimethacrylate
G-ænial Anterior	GC Corporation, Tokyo, Japan	Microhybrid	Silica, Stronsium, Lantanoid floride.	Weight %76, Volume %65 , 16-17 µm	UDMA, Dimetacrilate comonomer

Table 2 Descriptive and statistical datas of translucency parameter (TP)

					Mean		Normality	Homogenity	ANOVA
Groups	Mean	SS	Min.	Max.	Min 95%	Max 95%	Shaphiro-Wilk p-value	Levene's test p-value	F, p-value
1	24.32^{B}	1.15	21.88	26.21	23.59	25.05	0.250		
2	20.71^{D}	0.71	19.26	22.12	20.26	21.17	0.422		
3	17.14^{F}	0.87	15.59	18.24	16.58	17.69	0.642	F=2.30	F=143.07
4	26.87^{A}	1.52	24.54	29.71	25.90	27.83	0.757	p=0.0543	P<0.0001
5	22.32^{C}	0.70	20.93	23.32	21.88	22.76	0.180		
6	19.29^{E}	0.88	17.52	20.67	18.73	19.85	0.974		
General	21.77	3.37	15.59	29.71	20.98	22.57	0.341		

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Table 3 Descriptive and statistical datas of opalescence parameter (OP-BW)

					Mean		Normality	Homogenity	ANOVA
Groups	Mean	SS	Min.	Max.	Min 95%	Max 95%	Shaphiro-Wilk p-value	Levene's test p-value	Mean
1	16.51^{A}	0.69	14.84	17.21	16.07	16.95	0.892		
2	15.56^{B}	0.48	14.43	16.38	15.25	15.86	0.821		
3	13.46^{D}	0.71	12.43	14.67	13.01	13.91	0.317	F=1.06	F=47.69
4	15.97^{B}	0.45	15.32	16.91	15.69	16.26	0.891	p=0.3897	P<0.0001
5	15.54^{B}	0.41	15.01	16.13	15.27	15.80	0.822		
6	14.38^{C}	0.55	13.29	15.23	14.03	14.73	0.960		
General	15.24	1.16	12.43	17.21	14.96	15.51	0.740		

Table 4 Descriptive and statistical datas of masking efficacy (ME)

					Mean		Normality	Homogenity	ANOVA
Groups	Mean	SS	Min.	Max.	Min 95%	Max 95%	Shaphiro-Wilk p-value	Levene's test p-value	F, p-value
1	13.09^{E}	0.47	12.33	14.20	12.79	13.39	0.281		
2	16.12^{C}	0.72	15.02	17.15	15.66	16.57	0.676		
3	17.63^{B}	0.77	16.64	19.15	17.14	18.12	0.573	F=1.24	F=143.09
4	14.23^{D}	0.98	11.95	15.69	13.61	14.85	0.351	p=0.300	p<0.0001
5	17.56^{B}	0.70	16.61	18.83	17.12	18.01	0.655		
6	19.85^{A}	0.53	18.86	20.56	19.51	20.19	0.310		
General	16.41	2.37	11.95	20.56	15.85	16.97	0.200		

Table 5 Results of Pearson correlation test

	OP-BW	TP	ME
OP-BW	1	0.8600	-0.6790
		p<0.0001	p<0.0001
TP		1	-0.7281
			p<0.0001
ME			1

Researchers have not intensively focused on the optical characteristics of materials, and very important developments on this topic could not be recorded (23). The focal point of studies carried out after this year has been the effects of polymers, fillers and thickness on translucency (20, 24, 25). Kamishima et al. prepared samples in five different thicknesses from two different resin composites and evaluated the correlation between the thickness increase and translucency by using the TP formulation. The researchers reported in the results of the study that the highest TP value in two composites was obtained in the samples with the thickness of 0.5 mm and that a statistically significant decrease in the TP value was recorded as the thickness was increased. Moreover, they emphasized that the clinically acceptable thickness value for the TP value is 2 mm, and a value measured above this value was below the clinical threshold value of 1.1 mm which was determined by Gross et al. (23, 24). In a similar study evaluating the interaction between the translucency values and thickness increase of enamel, dentin and body composites, it has been reported that a statistically significant negative correlation was found in all groups (25). In recent years, researchers have focused on the translucency change in 'sandwich restorations' in which dentin-like restorative materials are restored with resin-based composites. In a study investigating the correlation between the thickness increase and the TP in resin composites mimicking the enamel layer, it has been reported that a decrease was observed in the TP value with thickness increase in both microhybrid and nanohybrid composites. However, although clinicians are recommended to restore dentin restorative materials with microhybrid or nanohybrid composites with a thickness of 2 mm, researchers have indicated that it produces negative aesthetic results, and that it is possible to obtain more aesthetic results with a thickness of 1 mm (26). Our study results are also parallel with this literature data. There was a statistically significant decrease in the TP values with thickness increase in the nanohybrid and microhybrid composite groups which composed our study groups, and a negative correlation was found between the two parameters. Moreover, a statistically significant difference was observed between nanohybrid and microhybrid composites in our study, and the highest TP value was obtained in the microhybrid group with 1mm thickness. In a study comparing the TP values of microfilmed and microhybrid composites, it has been revealed that microhybrid composites had higher TP values in similar thicknesses (27). In a study investigating the TP values of nanohybrid and microhybrid composites, it has been emphasized that nanohybrid composites of different brands had similar TP values; however microhybrid composites exhibited higher TP values than the other groups (26).

Opalescence, also known as the opal effect, is the scattering phenomenon of the short-wavelength light of the visible spectrum in translucent materials (28). The opalescence of aesthetic restorations is often measured by the opalescence parameter (OP), which is derived from the difference between the yellow-blue color coordinate and the red-green coordinate of the CIE Lab color space (29, 30). For the OP formulation, it is necessary for researchers to make spectrophotometric

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measurements in reflectance and transmitted mode, and the studies conducted have clearly revealed that the OP parameter is affected by the sample thickness (31, 32). Therefore, the results of spectrophotometric measurements made by Lee in 2016 introduced a new index to literature, called the OP-BW, which can be calculated more easily. As indicated by the researchers, there is limited study on the OP-BW index, and the mathematical differences or correlation between the OP and OP-BW index have not been defined yet (29). Considering this lack in the literature, the opalescence values of our sample groups were calculated by using the OP-BW index. There is limited research on the opalescence of resin composites, and the focal point of existing studies is the effects of thickness increase, different light sources, and accelerated aging on the measured opalescence value (31, 33-35). In a study by Arimoto et al., the opalescence values of three different resin composites in different thickness were measured by using the OP index. In the study results, it has been emphasized that there was an increase in the OP value following thickness increase in all groups independently of the brands, and that the researchers found a positive correlation between the thickness and the OP value (31). Unlike these results, a decrease was observed in the opalescence values calculated by using the OP-BW index with the increase of sample thickness and a statistically significant but negative correlation was found between the thickness and the OP value in our study results. The correlation between these differences in our study data is thought to be due to the use of two different indices that have not been defined yet.

According to the minimally invasive concept, which is becoming more and more important nowadays, it is essential to protect the dental tissue as much as possible; however, this means that discolored areas will remain on the prepared surfaces (17, 36). The studies concentrated on this dilemma have introduced the definition of masking efficacy to the literature (1, 37, 38). The studies addressing the masking efficacy are mostly concentrated on ceramics and derivative materials (38-40), while there is a limited literature investigating the masking efficacy of resin composites (37). As the common conclusion of these studies, it is indicated that the masking efficacy increases as material thickness increases regardless of the type of material (15, 38, 41). When our study results are reviewed, it is remarkable that there was an increase in the ME values both in the nanohybrid and microhybrid composite groups following thickness increase, and that there was a positive correlation between these two parameters. This data is consistent with the general literature. However, another important point to note in our study results is that the microhybrid composite groups exhibited higher ME values than the nanohybrid composite groups in similar thicknesses. In the literature, there is a researcher who has commented that the filler size may have effects on the masking efficacy (42), while there was no study focused on this point. As we did not, so far none of the earlier researches concluded the standard combination ratio for translucency, opalescence and masking efficacy. We could comment that the standard ratio could be related with lots of factors like filler size, material type etc.

CONCLUSION

Within the limitations of our study, the following conclusions were reached in the clinical use:

1. A decrease was observed in the TP, OP-BW values with thickness increase in the used composites, while an increase occurred in the masking efficacy.
2. Nanohybrid composites exhibited a higher opalescence than microhybrid composites in all thickness groups, while they exhibited a lower translucency and masking efficacy.
3. In general, there was a statistically significant and negative correlation between the masking efficacy and translucency parameter and opalescence values of the composites.
4. There is a statistically significant and positive correlation between the OP-BW and TP values of the composites.

Clinicians should consider that the thickness of the composite they use in the construction of aesthetic composite laminate can affect the translucency and opalescence values, and should not ignore the effect of the filler size on masking efficacy while the case selection is made.

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Beyza Unalan Degirmenci: She prepared the specimens, prepared the manuscript.
Alperen Degirmenci: He made the experiments and the statistical analysis.

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