Future Dental Journal

Volume 7 | Issue 2 Article 11

2021

Effect of Thickness on Translucency and Masking Ability of a Recently Developed Single-Shade Resin Composite with Enhanced Opacity: An In Vitro Comparative Study

Sayed Mohamed Ghorab
Mansoura University, sayedghorab@mans.edu.eg

Hagag Abd Elkader Atya
Mansoura University, hagag@mans.edu.eg

Recommended Citation

Ghorab SM, Atya HA. Effect of Thickness on Translucency and Masking Ability of a Recently Developed Single-Shade Resin Composite with Enhanced Opacity: An In Vitro Comparative Study. *Future Dental Journal*. 2022; 7(2):130-135. doi: https://doi.org/10.54623/fdj.70211.

Future Dental Journal Volume 7, Issue 2 (2021) 130—135

Contents lists available at Arab Journals Platform

Future Dental Journal

Journal homepage: https://digitalcommons.aaru.edu.jo/fdj/

Effect of Thickness on Translucency and Masking Ability of a Recently Developed Single-Shade Resin Composite with Enhanced Opacity: An In Vitro Comparative Study

Sayed Mohamed Ghorab[a,*] , **Hagag Abd Elkader Atya**[a]

a Mansoura University, Egypt

ARTICLE INFO

Discipline:
Restorative Dentistry

Keywords:
Composite resin,
Masking,
Translucency,
Thickness

* Corresponding author.
E-mail address:
sayedghorab@mans.edu.eg
(Sayed Mohamed Ghorab).

ABSTRACT

***Objective*:** This study aimed to evaluate the effects of thickness changes on translucency and masking ability of a recently developed single shade resin composite material with enhanced opacity comparing it with a traditional opaque-shade one.

***Material and methods*:** Two brands of composite resins; Omnichroma blocker (OCB) and G-aenial Anterior (GA) in opaque A2 (OA2) shade were selected to enroll the study. Color coordinates of each composite were determined at 0.5, 1, and 1.5mm thicknesses (n=10/thickness) on four different backgrounds (white baking, black baking, C4 shade porcelain baking and the backing of material itself) by using a spectrophotometer to determine the translucency parameter (TP) and masking ability of the study materials. Data were statistically analyzed using One-way ANOVA, T-test and Tukey HSD as a post hoc for multiple comparisons ($P < .05$).

***Results*:** TP and ΔE^* values obtained between specimens on different backgrounds decreased as thickness increased. For both materials, a black backing was masked by thicknesses of 1.5 mm, whereas a C4 porcelain backing was masked by all resin thicknesses.

***Conclusion*:** In relatively thin thicknesses (≤1mm), both composites could not mask the black background color. On the other hand, they could mask C4 porcelain background color at all thicknesses.

1. INTRODUCTION

Resin composite restorations are widely used in cosmetic dentistry because of their superior properties and low cost compared with ceramic restorations [1]. However, they require a proper shade matching procedure to achieve their best results. With the purpose of restoring different shades of teeth, dental manufacturers have developed various composites with different colors and/or translucencies. Nevertheless, shade matching procedure is very challenging and time-consuming since it involves selecting and maintaining a color match for the restoration [2].

For this reason, Tokuyama introduced the omnichroma shade matching composite that has gained a lot of popularity recently. According to the manufacturer, omnichroma utilizes a unique "smart chromatic technology" that allows it to match the color of the environment within its vicinity compared with the conventional composites containing dyes or pigments [3]. This procedure achieves its goal by optimizing the resin's translucency after curing. While appearing opaque white before curing, omnichroma achieves a natural look by transitioning from opaque to semi-translucent after curing [4]. However, its inherent translucency can set off some difficulties in shade matching, especially in cases of large class III and IV restorations or strictly stained tooth structures. In these cases, the translucency of composite resin restorations can be affected by the darkness of the oral cavity or even the discolored tooth structures resulting in a grayish shade or poor-color matching up [4,5].

Recently, a layering technique has been developed in order to reduce the effect of background color. Accordingly, the color of opaque-shade composite resin used as a background can affect the translucency of the composite resin restorative material [5-8]. Omnichroma blocker is a supplementary material with enhanced opacity (blocking agent) designed for use as a thin layer before placement of Omnichroma. In case of extensive class III and IV restorations, when there is limited surrounding dentition, this blocker can be placed at the lingual cavity wall to reduce shade-matching interference caused by other parts of the mouth. It can also mask slight staining or be used to reconstruct a highly opaque tooth. Generally, the translucency of composite resin materials can also affected by its thickness. However, the proper knowledge of differences in translucency and the required thickness to mask background of this applied novel opaque-shade composite resin seems to be essential, though little information is available.

Therefore, this study aimed to investigate the changes in translucency of a newly developed single shade resin composite with enhanced opacity as a result of changes in the thicknesses compared to a conventional opaque-shade microhybrid resin composite material. In addition, its ability to mask two different clinical situations (oral cavity darkness and discolored tooth structure) was assessed. The null hypotheses tested were that there were no significant differences in (1) translucency and (2) masking ability between the tested resin composites at different thicknesses.

2. MATERIALS AND METHODS

Two composites were used in this study: a single shade universal resin composite with enhanced opacity (Omnichroma blocker, Tokuyama Dental, Tokyo, Japan) and an opaque-shade microhybrid resin composite (G-aenial Anterior OA2, GC Corp., Tokyo, Japan). Compositions, manufacturers and batch numbers of the tested resin composite materials are presented in Table 1.

Table 1:

Materials used in the study.

Materials/ Codes	Shade	Composition	Manufacturer	Lot. No
Omnichroma blocker (OCB)	Single shade (Universal)	**The Filler System:** 82% by weight (71% by volume) of spherical silica- zirconia filler (mean particle size: 0.2µm, particle size range: 0.1 to 0.3µm) and composite filler. **The Resin System:** Bis-GMA and Triethylene glycol dimethacrylate	Tokuyama Dental, Tokyo, Japan	009E Y0
G-aenial Anterior (GA)	OA2	**The Filler System:** 76% by weight (65% by volume) Silica, Stronsium, Lanthanoid fluoride (Particle size: 16-17 µm). **The Resin System:** UDMA, Dimethacrylate comonomer	GC Corporation, Tokyo, Japan	1912 16A

2.1 Specimen preparation

A total of sixty disc-shaped standardized specimens (n=30/ material) were prepared using split teflon molds in 0.5, 1 or 1.5 mm thicknesses and with a hole of 10 mm in diameter (n= 10/thickness). The composites were inserted into the molds on a Mylar matrix. After that, the specimen's surfaces were sheltered by another Mylar matrix and a glass plate. Half kg customized metallic tool was applied as a standardized constant pressure for 10 minutes to get a uniform standardized specimens' thickness. Then, metallic tool was removed and the curing light was placed perpendicular to each specimen's surface and with direct contact with the glass slide. Curing was performed according to manufacturer's instructions with a LED light curing unit (BlueLEX LD-105, Monitex Industrial Co., LTD. Taiwan, light output: 1000 mW/cm^2) through the glass slide and Mylar strip on the top of the specimens once being pressed. A radiometer (Demetron/Kerr, CT-100, Danbury, USA) was utilized to check the light curing output. Then, the specimen surfaces were rubbed for standardization with the 800, 1000 and 1200-grit water sandpapers (MicrocutTM, Buehler, Lake Bluff, USA) by a single operator for 10 seconds per each grit size and then immersed in distilled water at 37°C for 24 hours in the incubator (Hanautherm, Original Hanau Lab., Germany).

2.2 Color measurements

The CIE L*a*b*(CIELAB) technique was employed in the present study. This technique is introduced by the International Commission on Illumination (French Commission Internationale de l'éclairage (CIE) which is an organization that establishes the standard values used worldwide to measure color. The values used by CIE are called L*, a* and b* and the color measurement method is called CIE L*a*b* (CIELAB). L* denotes to the lightness which ranged from zero (black) to 100 (white). The a* and b* are the chromaticity coordinates in the red- green axis (–a* = green and +a* = red) and the yellow-blue axis (–b*= blue and +b* = yellow) respectively [8].

In the current study, four different backgrounds; white baking (CIE L* = 98.35, a* = - 0.2, and b* =1.16), black baking (CIE L* = 2.88, a* = - 0.12, and b* = - 1.09), C4 shade porcelain baking (CIE L*= 65.56, a* = 1.23, b* =13.50, Vita VMK68, Vita Zahnfabrik, Bad Säckingen, Germany) and resin itself were used to determine the translucency parameter (TP) (between black and white backing), and to simulate two different clinical situations; the oral cavity darkness (between black and resin backings) and discolored tooth structure (between C4 shade porcelain and resin backings) [8,9].

To determine the CIELAB values of each specimen with each background, color measurements were performed using a spectrophotometer (Cary 5000 UV-Vis-NIR, Agilent Technologies, USA) in the reflectance mode relative to the standard illuminants D65 excluding the ultraviolet light. The aperture size was 3 mm, and the illuminating and viewing configurations were CIE diffuse/8° geometry. Considering the optical contact between the specimen and the backings, saturated sucrose solution was used to reduce the edge-loss effect. According to the manufacturer's instructions, calibration was performed before each color measurement. An average of three measurements was performed for each specimen [8].

2.3 Translucency measurement

Translucency was measured in terms of translucency parameter (TP). The differences in CIELAB color coordinates between the white and black backgrounds were calculated to obtain the translucency parameter (TP) of the material at various thicknesses using the following equation [5,10-12]:

$$TP = [(L^*_W - L^*_B)^2 + (a^*_W - a^*_B)^2 + (b^*_W - b^*_B)^2]^{1/2}$$

Where the subscripts W and B refer to color coordinates over the white and black background respectively. A higher value for the translucency parameter represents greater translucency.

2.4 Masking ability measurement

CIELAB color differences (ΔE^*) were also calculated for each thickness on the backgrounds simulating two different clinical situations; the oral cavity darkness (between black and resin backgrounds) and discolored tooth structure (between C4 shade porcelain and resin backgrounds) according to the following formula:

$$(\Delta E^*) = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$$

A smaller ΔE* indicates that the specimen is less sensitive to (as in better able to mask) the black and C4 porcelain backgrounds color. The ΔE*value was assessed for each thickness and the opaque resin thickness sufficient for masking a background was determined through the clinically acceptable ΔE* range ($\Delta E^* \leq 2.7$) [13,14]. This thickness was termed the critical thickness.

Statistical analysis

Data were analyzed using SPSS program (SPSS v22.0; SPSS Inc). Test of normality was performed using Shapiro Wilk test and homogeneity of variances by the Levene's test. The data (translucency, masking effect against oral darkness, masking effect against discolored tooth) were normally distributed and presented as mean ± standard deviation for descriptive statistics. One Way ANOVA was used to evaluate the effect of different thicknesses in each composite followed by Tukey's multiple comparisons if significant differences were detected. Comparisons of data between each material for each thickness were performed by independent sample t-test. P was significant at 5%.

https://digitalcommons.aaru.edu.jo/fdj/vol7/iss2/11
DOI: https://doi.org/10.54623/fdj.70211

3. RESULTS

Comparison of translucency between materials and different thicknesses is presented in Table 2. For both materials, there was a significant difference in translucency between different thicknesses ($p<0.001$ for both materials). The higher translucency was observed with 0.5mm thickness, followed by 1mm thickness and the lower translucency was noted with 1.5 mm. Multiple comparisons between each two thickness are presented in Table 2 and Figure 1. For each material, there was a significant difference between each two thickness. For each thickness, there was a significant difference between materials ($p<0.001$ for all thicknesses). G-ænial Anterior demonstrated significant higher translucency than Omnichroma blocker for all thicknesses.

Table 2

Comparison of translucency between materials and different thickness.

	Omnichroma blocker		G-ænial Anterior		Indepen dent samples t-test (Pvalue)
	X	SD	X	SD	
0.5 mm thickness	10.63a	0.22	16.41a	0.20	<0.001*
1mm thickness	7.46b	0.16	11.80b	0.18	<0.001*
1.5mm thickness	4.28c	0.15	6.89c	0.20	<0.001*
One Way ANOVA (p value)	<0.001*		<0.001*		

X; mean, SD, standard deviation, The same superscript letters in the same columns showed no significant difference between each 2 thickness (Tukey, p>0.5), Different letters in the same columns showed a significant difference between each 2 thickness (Tukey, p<0.5), *p is significant at 5%.

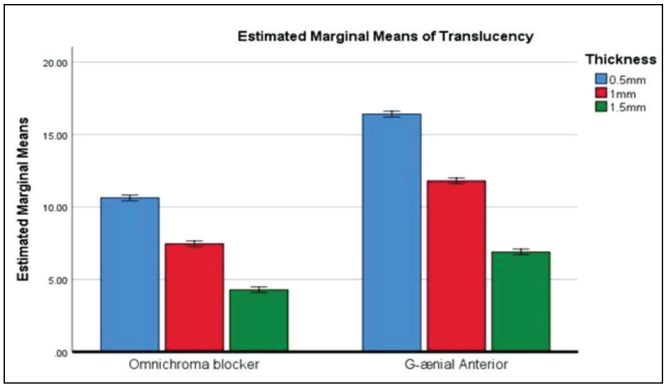

Figure (1) — Comparison of translucency between different thicknesses for both composite resins.

Comparison of masking effect against oral darkness between materials and different thicknesses is presented in Table 3. For both materials, there was a significant difference in masking effect against oral darkness between different thicknesses ($p<0.001$). The lower masking effect was observed with 0.5 mm thickness, followed by 1mm thickness and the higher masking effect was noted with 1.5 mm. Multiple comparisons between each two thickness are presented in Table 3 and Figure 2. For Omnichroma blocker composite, no significant difference between 0.5 mm and 1 mm thickness was observed. However, a significant difference was observed between the other thicknesses. For G-ænial Anterior composite, there was a significant difference between each two thickness. For 0.5 mm and 1.5 mm thickness, there was a significant difference between materials ($p<0.001$). However, for 1 mm thickness, no significant difference between materials was noted. For 0.5 mm and 1.5 mm thickness, G- ænial Anterior demonstrated significant lower masking effect against oral darkness than Omnichroma blocker. For both materials, the ΔE* values recorded for the 1.5 mm-thick specimens were in the range of imperceptible ($\Delta E^* \leq 2.7$). However, both materials at 0.5- and 1- mm- thicknesses could not mask the black background.

Table 3

Comparison of masking effect against oral darkness between materials and different thickness.

	Omnichroma blocker		G-ænial Anterior		Independent samples t- test (P value)
	X	SD	X	SD	
0.5 mm thickness	4.07[a]	0.18	6.77[a]	0.23	<0.001*
1mm thickness	3.87[a]	0.20	3.88[b]	0.18	1.00
1.5mm thickness	0.81[b]	0.08	1.61[c]	0.10	<0.001*
One Way ANOVA (p value)	<0.001*		<0.001*		

X; mean, SD, standard deviation, The same superscript letters in the same columns showed no significant difference between each 2 thickness (Tukey, p>0.5), Different letters in the same columns showed a significant difference between each 2 thickness (Tukey, p<0.5), *p is significant at 5%.

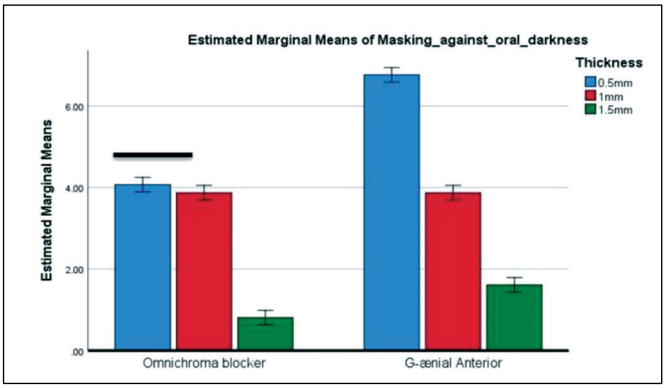

Figure (2) — Comparison of masking effect against oral darkness between different thicknesses for both materials.

Comparison of masking effect against discolored tooth between materials and different thicknesses is presented in Table 4. For Omnichroma blocker composite, no significant difference in masking effect against discolored tooth between different thicknesses was observed ($p=0.098$). For G-ænial Anterior, there was a significant difference between thicknesses ($p<0.001$). The lower masking effect was observed with 0.5mm thickness, followed by 1mm thickness and the higher masking effect was noted with 1.5 mm. Multiple comparisons between each two thickness are presented in table 4 and Figure 3. For G-ænial Anterior composite, no significant difference between 1 mm and 1.5 mm thickness was observed. However, a significant difference was observed between the other thicknesses. For 0.5 mm thickness, there was a significant difference between materials ($p<0.001$). However, for 1 mm and 1.5 mm thicknesses, no significant difference between materials was noted. For 0.5 mm thickness, G- ænial Anterior demonstrated significant lower masking effect against discolored tooth than Omnichroma blocker. The ΔE* values recorded were in the range of imperceptible ($\Delta E^* \leq 2.7$) for both materials at all thicknesses. Therefore, both materials could mask the discolored tooth at all thicknesses.

Table 4

Comparison of masking effect against discolored tooth between materials and different thickness.

	Omnichroma blocker		G-ænial Anterior		Independent samples t- test (P value)
	X	SD	X	SD	
0.5 mm thickness	0.70a	0.14	1.63a	0.28	<0.001*
1mm thickness	0.49a	0.25	0.52b	0.20	0.881
1.5mm thickness	0.36a	0.15	0.39b	0.20	0.829
One Way ANOVA (p value)	0.098		<0.001*		

X; mean, SD, standard deviation, The same superscript letters in the same columns showed no significant difference between each 2 thickness (Tukey, p>0.5), Different letters in the same columns showed a significant difference between each 2 thickness (Tukey, p<0.5), *p is significant at 5%.

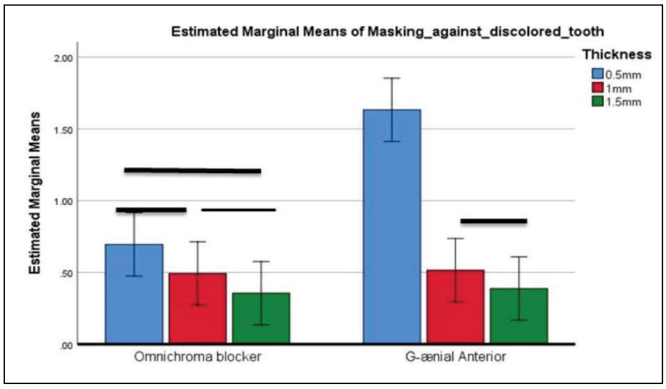

Figure (3) — Comparison of masking effect against discolored tooth between different thicknesses for both materials.

4. DISCUSSION

The demand for better aesthetics and function is inducing the evolution of resin composite materials with an all in one technology. As a result, clinicians are searching for materials that are more user-friendly, time saving and are pleasing to the patient's high prospects [15]. OMNICHROMA is a single shade composite that eliminates the need for shade selection, bleaching over restorations or replacing the filling if it gets stained [4].

Although the human eye can detect the change in color difference, it is a technical challenge to achieve shade matching especially in cases where there is little or no tooth structure surrounding the restoration such as extensive Class III and Class IV restorations, or in severely stained tooth structure[6,16]. Consequently, in these cases, a single shade resin composite with enhanced opacity (Omnichroma Blocker) is used as a blocking/masking agent and placed as a thin layer before placement of Omnichroma. This mask helps in concealing the inner portion of the tooth structure, which is vulnerable to staining and shade- matching interference caused by the presence of discoloration. Up to the knowledge of authors, there is scarce of data regarding the evaluation of the translucency and masking ability of this novel opaque resin composite material at different thicknesses. Accordingly, this study was performed to evaluate and compare the changes in translucency and masking efficacy of two different opaque shade composite resins, a newly developed single shade resin composite with enhanced opacity and a conventional opaque-shade microhybrid resin composite material, as a result of changes in the thicknesses. These two products were selected due to their relative popularity and acceptance by clinicians [3,7].

Changing the backgrounds can alter the final color differences [17]. Therefore, black and porcelain backgrounds were used in the present study. Black background can mimic the oral cavity darkness especially in 'through and through' class III and IV cavities [7,10], whereas; porcelain background can simulate a discolored tooth shade since it has the darkest L* value in the classical shade guide [18].

The results of the current study revealed that translucency was significantly different between the tested materials (p<0.001) at all thicknesses. Therefore, the first null hypothesis was rejected. Also, the results showed that there was a significant difference in masking effect against oral darkness between materials (p<0.001) for 0.5 mm and 1.5 mm thickness. However, no significant difference between materials was noted for 1 mm thickness. Moreover, there was a significant difference in masking effect against discolored tooth between materials (p<0.001) for 0.5 mm thickness. However, for other thicknesses, no significant difference between materials was noted. So, the second null hypothesis was partially rejected.

Translucency is a condition where a material can partially pass the light through [19]. Apart from its thickness, various factors affect the translucency of composite resin. These include the coefficient of resin scattering and absorption, the type of filler particles, and on the coloring agent and opacifiers the material contains [20]. 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) [21], whereas TP value indicates the color difference between black and white backgrounds of a material in certain thickness [14]. A higher value for the translucency parameter represents greater translucency; if the material is completely opaque, the value of this parameter is zero. The translucency parameter 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, and it is revealed that it produces a mathematical result supporting the clinical observations of the conducted studies [21,22-24]. In our study, the TP formulation was used to calculate the translucency changes taking into consideration all these literature data.

The results of the present study showed 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 increase. Therefore, there is a negative relationship between TP values and thicknesses. This result is in agreement with previous studies [6,25]. The results also showed that Omnichroma blocker composite demonstrated significant lower translucency than G-aenial Anterior. This can be explained on the basis that Omnichroma blocker is a supra nanofill type composite that contains fine, uniform, and a relatively large amount of 0.2 μm monodispersing spherical filler. This unique filler morphology might affect the light transmission, reflection, and scattering, which affected the translucency of this composite differently from that of other composites in TP measurement [26,27].

The masking efficacy (ME) is a description used to compare the ability of composite resins to mask existing discolorations at the lower background. 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 [28,29], thereby the use of more opaque composites before using a composite with translucency similar to enamel is recommended to mask a colored tooth tissue [30].

In this study, the ΔE* values of the tested composites for masking dark background or discolored tooth showed a negative relationship with their thickness. This means that there was an increase in the ME values in both composite materials following thickness increase. This result is in agreement

https://digitalcommons.aaru.edu.jo/fdj/vol7/iss2/11
DOI: https://doi.org/10.54623/fdj.70211

with previous studies [5,6,31]. The perceptible or clinically acceptable color difference thresholds vary depending on the references used. The threshold for clinically accepted color difference has been reported as $\Delta E^* \leq 2$ [32], $\Delta E^* \leq 2.7$ [13,14], $\Delta E^* \leq 3.3$ [33], $\Delta E^* \leq 3.48$ [34], and $\Delta E^* \leq 3.7$ [35]. The current study followed Paravina et al [13] ($\Delta E^* \leq 2.7$) and Ragain et al [14] ($\Delta E^* \leq 2.7$) as this color difference is midway between those values reported by Ruyter et al [33] ($\Delta E^* \leq 3.3$) and O'Brien et al [32] ($\Delta E^* \leq 2$). Accordingly, the results showed that none of the studied composite resins in our study masked the background darkness when used in 0.5-1 mm thickness. However, they could mask black background in 1.5 mm thickness successfully. However, ΔE^* values recorded for masking effect against discolored tooth were in the range of imperceptible ($\Delta E^* \leq 2.7$) for both materials at all thicknesses. Therefore, both materials could mask the discolored tooth at all thicknesses.

The results also showed that Omnichroma blocker composite material exhibited higher ME values than the microhybrid composite one in similar thicknesses. This may be attributed to the lower transluceny related to Omnichroma blocker composite materials. The masking efficacy is clinically indicates the opposite of translucency [7].

One of the limitations of this study is the absence of specimens with thicknesses between 1 and 1.5 mm and it is recommended to be assessed in future studies. In addition, the clinical performance assessment is required to provide reliable recommendations for this in vitro study.

5. CONCLUSIONS

Within the limitations of this study and based on the results, the followings could be concluded:

- A decrease was observed in the TP values with thickness increase in the used composites, while an increase occurred in the masking efficacy.
- Omnichroma blocker composites exhibited a higher masking efficacy than G-aenial Anterior microhybrid composites in all thickness groups, while they exhibited a lower translucency.
- In relatively thin thicknesses (≤1mm), both composites could not mask the black background color. On the other hand, they could mask C4 porcelain background color at all thicknesses.

Conflict of interest

The authors have no conflicts of interest relevant to this article.

6. REFERENCES

1. Azeem RA, Sureshbabu NM. Clinical performance of direct versus indirect composite restorations in posterior teeth: a systematic review. J Conserv Dent 2018;21:2–9.
2. Sanchez N, Powers J, Paravina R. Instrumental and visual evaluation of the color adjustment potential of resin composites. J Esthet Restor Dent 2019;31:465–70.
3. Kevin B. How to match any composite restoration shade: Tokuyama's Omnichroma uses smart chromatic technology to match a wider range of natural teeth colors. Dent Prod Rep 2019;53:36.
4. Mohamed MA, Afutu R, Tran D, et al. Shade matching capacity of Omnichroma in anterior restorations. J Dent Sci 2020;5:1–6.
5. Kamishima N, Ikeda T, Sano H. Color and translucency of resin composites for layering techniques. Dent Mater J 2005;24:428–32.
6. Kim SJ, Son HH, Cho BH, Lee IB, Um CM. Translucency and masking ability of various opaque-shade composite resins. J Dent 2009;37:102–7.
7. Degirmenci BU, Degirmenci A. The effects of thickness changes in different composites on translucency, opalescence, and masking efficacy. Med Sci 2018;22:571–6.
8. Darabi F, Radafshar G, Tavangar M, Davaloo R, Khosravian A, Mirfarhadi M. Translucency and masking ability of various composite resins at different thicknesses. J Dent Shiraz Univ Med Sci 2014;15:117– 122.
9. An JS, Son HH, Qadeer S, Ju SW, Ahn JS. The influence of a continous increase in thickness of opaque shade composite resin on masking ability and translucency. Acta Odontol Scand 2013;71:120–9.
10. Lee YK, Powers JM. Color and optical properties of resin-based composites for bleached teeth after polymerization and accelerated aging. Am J Dent 2001;14:349–54.
11. Paravina RD, Ontiveros JC, Powers JM. Curing-dependent changes in color and translucency parameter of composite bleach shades. J Esthet Restor Dent 2002;14:158–66.
12. Johnston WM, Ma T, Kienle BH. Translucency parameter of colorants for maxillofacial prostheses. Int J Prosthodont 1995;8:79–86.
13. Paravina RD, Ghinea R, Herrera LJ, et al. Color difference thresholds in dentistry. J Esthet Rest Dent 2015; 27(suppl 1):s1–9.
14. Ragain Jr. Color acceptance of direct dental restorative materials by human observers. Color Research and Application 2000; 25:278–85.
15. Abdelraouf RM, Habib NA. Color-matching and blending-effect of universal shade bulk-fill-resin-composite in resin-composite-models and natural teeth. BioMed Res Int 2016: 4183432.
16. Douglas RD, Brewer JD. Acceptability of shade differences in metal ceramic crowns. J Prosthet Dent 1998;79:254–60.
17. Yeh CL, Powers JM, Miyagawa Y. Color of selected shades of composites by reflection spectrophotometry. J Dent Res 1982;61:1176–9.
18. Li Y. Tooth color measurement using Chroma Meter: techniques, advantages, and disadvantages. J Esthet Restor Dent 2003; 15:S33–41.
19. Kelly JR, Benetti P. Ceramic materials in dentistry: historical evolution and current practice. Aust Dent J 2011;56 (Suppl 1):S84–96.
20. Kim IJ, Lee YK. Changes in color and color parameters of dental resin composites after polymerization. J Biomed Mater Res B Appl Biomater 2007;80:541–6.
21. Li Q, Xu BT, Li R, Wang YN. Spectrophotometric comparison of translucent composites and natural enamel. J Dent 2010;38 (Suppl 2):e117–22.
22. Mikhail SS, Schricker SR, Azer SS, Brantley WA, Johnston WM. Optical characteristics of contemporary dental composite resin materials. J Dent 2013;41:771–8.
23. Yu B, Lee YK. Comparison of stabilities in translucency, fluorescence and opalescence of direct and indirect composite resins. Euro J Esthet Dent 2013;8:214–25.
24. Horie K, Nakajima M, Hosaka K, et al. Influences of composite-composite join on light transmission characteristics of layered resin composites. Dent Mater 2012;28:204–11.
25. Ardu S, Rossier I, di Bella E, Krejci I, Dietschi D. Resin composite thickness' influence on L*a*b* coordinates and translucency. Clin Oral Investig 2019;23:1583–6.
26. Tokuyama Dental Corporation (2011) Technical Report Tokuyama Dental, Tokyo, Japan.
27. Kim DH, Park SH. Evaluation of resin composite translucency by two different methods. Oper Dent 2013,38:E76–E90.
28. Shadman N, Kandi SG, Ebrahimi SF, Shoul MA. The minimum thickness of a multilayer porcelain restoration required for masking severe tooth discoloration. Dent Res J 2015;12:562–8.

29. Torres CR, Borges AB. Color masking of developmental enamel defects: a case series. Oper Dent 2015;40:25–33.

30. Heller A. Clinical procedures to avoid the 'dark halo' in restorations with direct composite resins (Introducing the concept of destructive interference in restorative dentistry). Dental Update 2011;38:304–6.

31. Ryan EA, Tam LE, McComb D. Comparative translucency of esthetic composite resin restorative materials. J Can Dent Assoc 2010;76: a84.

32. O'Brien WJ, Groh CL, Boenke KM. A new, small-colordifference equation for dental shades. J Dent Res 1990;69:1762–4.

33. Ruyter IE, Nilner K, Moller B. Color stability of dental composite resin materials for crown and bridge veneers. Dent Mater 1987; 3:246–51.

34. Cengiz S, Yüzbaşioğlu E, Cengiz MI, Velioğlu N, Sevimli G. Color stability and surface roughness of a laboratory-processed composite resin as a function of mouth rinse. J Esthet Restor Dent 2015;27:314–21.

35. Johnston WM, Kao EC. Assessment of appearance match by visual observation and clinical colorimetry. J Dent Res 1989;68:819–22.

https://digitalcommons.aaru.edu.jo/fdj/vol7/iss2/11
DOI: https://doi.org/10.54623/fdj.70211