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Masking Ability and Translucency of Direct Gingiva-Colored Resin-Based Restorative Materials

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Abstract: This study aimed to investigate the effects of shade, thickness, and the application of an opaquer on the masking ability and translucency of direct gingiva-colored giomer. Five shades of giomer, namely Gum-Light-Pink, Gum-Dark-Pink, Gum-Brown, Gum-Violet, and Gum-Orange, were evaluated at thicknesses of 0.5, 1.0, 1.5, and 2.0 mm. Color measurements were obtained using a spectrophotometer against white, black, and giomer backgrounds. The results were analyzed using the CIEDE2000 color-difference formula and interpreted based on the 50:50% thresholds for excellent perceptibility ($\Delta E_{00} < 1.1$) and acceptability ($\Delta E_{00} < 2.8$). Measurements were repeated after applying an opaquer. Acceptable masking ability was achieved at 0.5 mm for all shades. Excellent masking ability was achieved at 1.5 mm for all shades, except Gum-Brown, which required 1.0 mm. The opaquer increased masking ability in all specimens. Translucency decreased as thickness increased ($p < 0.0001$). Gum-Brown and Gum-Light-Pink, as well as Gum-Orange and Gum-Dark-Pink, demonstrated similar translucency at 0.5, 1.0, and 1.5 mm ($p > 0.05$). After applying the opaquer, there were no statistically significant differences in translucency among shades at 1.5 mm and 2.0 mm ($p > 0.05$). In conclusion, increasing thickness improved masking ability but reduced translucency of gingiva-colored material. The opaquer further enhanced masking ability and reduced translucency. The clinical significance of these results are that gingiva-colored restorations mask discolored tooth defects in the pink aesthetic area with minimal 0.5 mm tooth preparation, achieving acceptable results. The addition of an opaquer enhances masking ability for excellent outcomes.

Keywords: gingiva-colored restoration; masking ability; translucency; spectrophotometry; giomer

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1. Introduction

Smile attractiveness is influenced by multiple factors, with gingival display playing a significant role [1]. In clinical practice, gingival recession—a condition characterized by the displacement of the gingival margin below the cementoenamel junction (CEJ)—is commonly encountered [2]. Gingival recession indicates the loss of supporting periodontium, exposing the root surface [3]. The impact of gingival recession extends beyond physiological issues, leading to potential complications such as dentin hypersensitivity, root caries, and non-carious cervical lesions. Additionally, gingival recession can compromise smile aesthetics by disrupting the balance between the pink and white components, creating an uneven appearance and exposing an unnatural tooth shape [3]. Root exposure due to recession is also more susceptible to caries and can result in yellow-brown discoloration in the cervical area, further detracting from the smile's aesthetic appeal. Contributing factors to gingival recession include chronic inflammation, periodontal disease, traumatic occlusion, and aggressive tooth-brushing habits [4,5].

To restore compromised pink aesthetics, either periodontal surgery or direct gingiva-colored restoration are considered [6]. Surgical treatment is generally the preferred approach for addressing gingival recession as it yields aesthetically pleasing results and enables optimal root coverage [7]. However, limitations exist depending on factors such as lesion size, graft tissue thickness, and anatomical considerations [8]. For patients with surgical contraindications or those hesitant to undergo surgical intervention, direct gingiva-colored restoration can be proposed as a viable alternative [9–11]. Moreover, when dealing with cervical tooth defects associated with gingival recession that have led to an elongated clinical crown, it is essential to first restore the lost crown structure with tooth-colored restorative material. A gingiva-colored material, such as a giomer, can be applied subsequently to restore the nearest cervical region and achieve the most natural outcome for the teeth [12,13].

Introduced in 1988, giomer is a dental material that combines the aesthetic properties of resin composites with the antibacterial benefits of glass ionomers. Giomers release fluoride, hydroxyl, and calcium ions, which help combat secondary caries, reduce demineralization, and neutralize acids produced by cariogenic bacteria [14–16]. This material is made with pre-reacted glass ionomer (PRG) filler particles in a resin matrix. PRG fillers are classified as fully reactive (F-PRG), which release fluoride entirely, and surface-reactive (S-PRG), which release six types of ions (Na^+, Sr^{2+}, Al^{3+}, F^-, BO^{33-}, SiO^{32-}) and offer rechargeability and antibacterial effects [16–18]. S-PRG fillers also reduce biofilm formation, though studies show they do not entirely prevent plaque accumulation, merely minimizing bacterial aggregation [19]. Additionally, S-PRG technology, used in certain giomers like Beautifill II, has been associated with lower plaque buildup and reduced bacterial adherence [20]. Due to these properties, giomers are highly biocompatible, with in vitro studies confirming their non-toxicity to human gingival fibroblasts and higher initial pH compared to traditional resin composites [21,22]. Giomer has proven effective in restoring Class I, II, and V lesions, demonstrating both short- and long-term durability [23–26]. While limited research exists on the optical properties of gingiva-colored giomers, studies show promising outcomes. For example, a two-year study on Amaris gingiva—a gingiva-colored composite—reported over 90% restoration retention with more than 65% achieving an excellent color match, suggesting its suitability for treating gingival recession and exposed root dentin [10]. Additionally, anaxGUM pink composite has shown success in restoring gingival recession and black triangle lesions, with high patient and clinician satisfaction reported after 18 months [27]. Gingiva-colored resin-based materials, including giomers, are versatile for managing recession and class V defects, even at minimal depths, while providing durable aesthetic results [28]. With antibacterial properties, biofilm reduction, and biocompatibility, giomers are highly suitable for both restorative and cosmetic applications, enhancing oral health and aesthetics [19–22].

A common challenge with gingiva-colored restorations is achieving an accurate color match to natural gingiva while effectively concealing discolored cervical lesions [29]. The appearance of these composites depends on optical and colorimetric properties influenced by background color and material thickness. Studies show that white backgrounds enhance color saturation and value, whereas dark backgrounds require a thicker material (up to 2 mm) with an opaquer for optimal masking [30–33]. For instance, a 1.0 mm layer of flowable tooth-colored giomer fails to mask a C3-shaded cavity, whereas a 2 mm thickness provides a better match, especially with opaque shades [31,34]. Research also indicates that background color significantly impacts translucency and masking effectiveness, as thicker and denser materials scatter more light, enhancing concealment and reducing translucency [35]. Translucency is vital in dental aesthetics but can pose challenges in achieving natural gingival colors due to background effects. This highlights the need for further study on the translucency and masking ability of gingiva-colored giomers against clinically relevant backgrounds for improved aesthetic outcomes [36].

Gingival recession presents both physiological and aesthetic challenges, necessitating effective management strategies [3–5]. Non-surgical options, including fluoride application and desensitizing agents, provide symptom relief, while surgical procedures remain the most effective for root coverage [6,7]. For patients reluctant to undergo surgery, direct gingiva-colored restorations offer a viable aesthetic alternative [6]. However, achieving a natural appearance depends on factors such as background color and material thickness, both of which significantly influence the final shade [36]. This study aims to ascertain the minimum thickness required for clinically acceptable masking ability and translucency in gingiva-colored materials, alongside evaluating the effects of thickness, shade, and the presence of an opaquer on their optical properties. The null hypotheses propose that material thickness has no significant impact on achieving acceptable masking and translucency, nor do variations in thickness, shade, and opaquer presence significantly affect the optical characteristics of gingiva-colored restorations. Enhanced understanding of these factors will support improved clinical outcomes for patients.

2. Materials and Methods

2.1. Specimen Preparation

Gingiva-colored giomer (Beautifil II Gingiva, Shofu Dental Corporation, Kyoto, Japan) composed of BisGMA, TEGDMA, S-PRG filler, initiator, pigments, and other components, was purchased and evaluated in this study. Five shades of this material were Gum-Brown (G-Br), Gum-Orange (G-Or), Gum-Dark Pink (G-DP), Gum-Violet (G-V), and Gum-Light Pink (G-LP). For each shade, four thicknesses (0.5, 1.0, 1.5, and 2.0 mm) were fabricated and 15 specimens in each thickness group were produced resulting in 300 specimens in total.

The sample size calculation for testing the translucency and masking ability of resin-based materials with four different thicknesses, using the G*Power program version 3.1.9.7, resulted in a requirement of 12 samples. This sample size ensures a predictive power of 80% with a significance level (α) of 0.05 and an effect size based on a previous study [31]. However, the present study chose to use a slightly larger sample size of 15, aiming to increase the study's robustness and enhance the reliability of the findings.

Fifteen specimens of each material shade and thickness were made by placing the material into a 10 mm diameter acrylic mold with four thicknesses (0.5, 1.0, 1.5, and 2.0 mm), as shown in Figure 1. The materials were pressed, and a 0.5 mm-thick cover glass was used to flatten and smooth the top surface. The front surface of the specimens was standardized using only a glass slide instead of a celluloid matrix. This choice was made due to the rigidity and smooth surface characteristics of the glass slide, which ensured standardization across all specimens' front surfaces. The bottom of the specimen was placed against a polished flat metal base, allowing for the adjustment of material thickness according to the research protocol. The materials were polymerized for 20 s using a light-curing unit (2000 mW/cm^2) (STALEC, mini-LED III, Acteon, Merignac, France) [12]. After polymerization, the specimens were then stored in 37° distilled water for 24 h in an incubator (Memmert GmbH + Co. KG, Schwabach, Germany). For standardization, the thickness of all specimens was evaluated by measuring with a digital vernier caliper with an accuracy of 0.05 mm. The specimens were then observed under the stereomicroscope to inspect the surface for air bubbles, cracks, and voids, as shown in Figure 2.

Figure 1. Fifteen specimens of 0.5 mm G-LP in an acrylic mold (numbers 1–15 indicate that there are 15 specimens tested in each group of material).

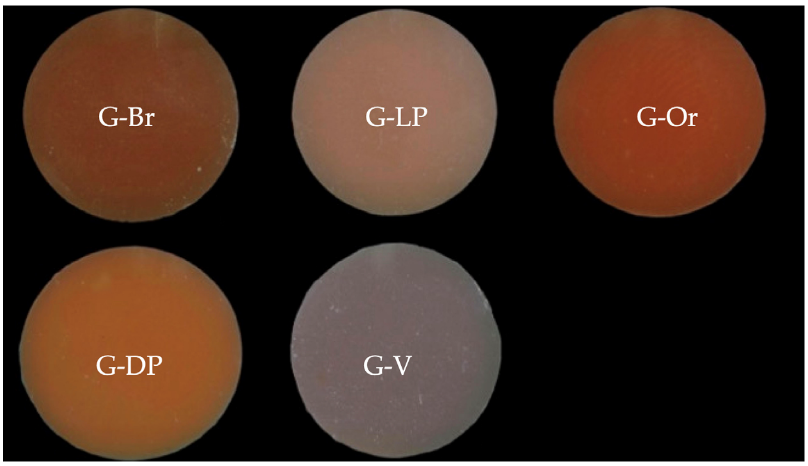

Figure 2. Gingiva-colored giomers observed under stereomicroscope at thickness of 1.5 mm. Gum-Brown (G-Br), Gum-Light-Pink (G-LP), Gum-Orange (G-Or), Gum-Dark-Pink (G-DP), and Gum-Violet (G-V).

2.2. Background Sample Fabrication

Seven backgrounds: white tile (L* = 98.61, a* = −0.58, b* = 1.84), black tile (L* = 0.20, a* = −0.00, b* = 0.14) (values obtained by spectrophotometry) [37], and five giomers (G-Br, G-Or, G-DP, G-V, and G-LP) were prepared. The background of gingiva-colored materials were pressed into an acrylic mold of 10 mm diameter at 2.5 mm thickness using the procedure mentioned above. The black background was used to mimic a discolored dark-brown cavity at the cervical carious lesion or discolored underlying dentin in gingival recession cases. The difference in color coordinates between the black background and the background of the resin itself was used to calculate the masking ability (ΔE_{00}) and to determine the sufficient thickness of direct restoration to mask a dark discolored cavity [32]. Two types of backgrounds were used to determine the translucency parameter (TP_{00}) (black and white backgrounds) [31]. According to the CIELAB color system, black and white colors represent the lowest (close to 0) and highest (close to 100) L* value on the center axis, respectively, indicating the maximum color difference. If the material at a selected thickness can mask the black background, it is considered capable of masking all substrate colors, including discolored brown carious lesions.

2.3. Color Measurement

Color measurements were acquired utilizing a spectrophotometer, namely the VITA Easyshade V (VITA Zahnfabrik, Bad Säckingen, Germany). The measurement setup was established within a controlled environment in a viewing booth (Figure 3). This environment incorporated specific conditions, including the utilization of CIE standard illumination D65, a light intensity of 10,000 lux, and a custom-designed 45-degree angle 3D printed specimen holder optimized for optical geometry, as shown in Figure 3 [38]. Throughout the measurement process, it was imperative for the measuring tip to maintain complete contact with the disc surface, ensuring that the measuring geometry corresponded to CIE 45°/0° using the specimen holder. The illuminance of the light source was standardized, a parameter regulated and verified by a Lux meter. This light intensity was selected based on optimal visual color assessment criteria outlined in ISO-TR 28642-2016 [39]. For each specimen, three measurements were conducted against three distinct backgrounds: white, black, and the background of the giomer itself. Subsequently, the obtained color values were calculated utilizing the CIEDE2000 color-difference formula and processed in an Excel spreadsheet [40]. To ensure the accuracy of measurements, the spectrophotometer underwent calibration before each use, incorporating a white balance procedure conducted on its calibration block in adherence to the manufacturer's guidelines.

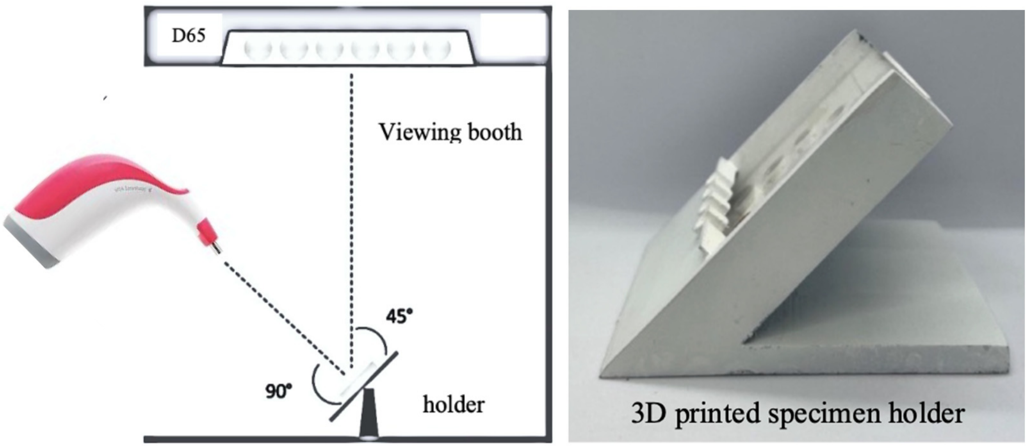

Figure 3. The measurement set-up showing a viewing booth and a 3D printed specimen holder.

2.4. Masking Ability (ΔE_{00}) Calculation

Masking ability for all shades and thicknesses was assessed against both the black background and the background of the giomer itself. The CIEDE2000 color-difference (ΔE_{00}) formula, as shown below, was employed to calculate these measurements.

$$\Delta E_{00} = \left[\left(\frac{\Delta L'}{K_L S_L} \right)^2 + \left(\frac{\Delta C'}{K_C S_C} \right)^2 + \left(\frac{\Delta H'}{K_H S_H} \right)^2 + R_T \left(\frac{\Delta C'}{K_C S_C} \right) \left(\frac{\Delta H'}{K_H S_H} \right) \right]^{\frac{1}{2}}$$

A higher ΔE_{00} implies a diminished capacity to mask the respective background. A comparison of ΔE_{00} to the perceptibility threshold (PT) and acceptability threshold (AT) at a 50:50% ratio indicated excellent masking ability if the ΔE_{00} value was below PT ($\Delta E_{00} < 1.1$). Additionally, a ΔE_{00} value falling within the range of PT to AT ($1.1 \leq \Delta E_{00} \leq 2.8$) signified acceptable masking ability, while a ΔE_{00} value surpassing AT ($\Delta E_{00} > 2.8$) indicated unacceptable masking ability [29]. The assessment of masking ability encompassed both the gingiva-colored giomer samples in isolation and those treated with an opaquer on the surface.

2.5. Translucency Parameter (TP_{00}) Calculation

Translucency for all shades and thicknesses was obtained against both black and white backgrounds. The translucency parameter (TP_{00}) was computed using the CIEDE2000 color-difference formula:

$$TP_{00} = \left[\left(\frac{L'_B - L'_W}{K_L S_L} \right)^2 + \left(\frac{C'_B - C'_W}{K_C S_C} \right)^2 + \left(\frac{H'_B - H'_W}{K_H S_H} \right)^2 + R_T \left(\frac{C'_B - C'_W}{K_C S_C} \right) \left(\frac{H'_B - H'_W}{K_H S_H} \right) \right]^{\frac{1}{2}}$$

A higher value of the translucency parameter (TP_{00}) signifies increased material translucency. TP_{00} calculations were performed for both the gingiva-colored giomers in their singular form and for samples treated with an opaquer applied to the surface.

2.6. Preparation of Specimen with an Opaquer

Upon completing color measurements to assess the material's masking ability and translucency, the effect of the opaquer was evaluated. A uniform layer of Beautifil Opaquer Universal Opaque (UO) shade (Shofu Dental Corporation, Kyoto, Japan) was applied consistently across all samples using single-used applicators to ensure consistent thickness and even coverage. The opaquer was carefully spread to eliminate air bubbles or gaps and polymerized for 20 s using a light-curing unit (STALEC, mini-LED III, Acteon, Lyon, France) at 2000 mW/cm^2, following the manufacturer's instructions. To ensure standardization, the opaquer's thickness was measured with a digital caliper with an accuracy of 0.1 mm at three points on each specimen (center and edges), maintaining a precise thickness of 0.5 mm. Additional validation was performed on randomly selected specimens to confirm reproducibility. The analysis was conducted across various background colors and material shades, encompassing four different thickness variations. This consistent measurement approach aimed to determine the opaquer's impact on the masking ability and translucency properties of the material.

2.7. Statistical Analysis

The data distribution, assessed through the Kolmogorov–Smirnov test and Levene's test for equality of variance, guided the application of non-parametric tests. One-Sample Wilcoxon signed-rank tests were utilized to compare the ΔE_{00} values against the 50:50% perceptibility ($\Delta E_{00} < 1.1$) and 50:50% acceptability thresholds ($\Delta E_{00} < 2.8$) for masking ability (ΔE_{00}). Univariate analysis by rank was employed to evaluate the interaction between shades and thicknesses in relation to ΔE_{00}. For pairwise comparisons between shades and thicknesses, the Bonferroni test (with a significance level of $p < 0.05$) was implemented. Wilcoxon signed-rank tests were employed to scrutinize the ΔE_{00} and TP_{00} values for specimens with and without the opaquer. The statistical analysis was conducted using the SPSS Statistics 25 software package (v26.0, IBM, Armonk, NY, USA).

3. Results

Table 1 presents CIEDE2000 color coordinates for five shades of gingiva-colored giomer at thicknesses of 0.5, 1.0, 1.5, and 2.0 mm. Technical difficulties hindered the acquisition of G-V shade values. These technical challenges concerning G-V values will be further addressed. At 0.5 mm, all giomers showed acceptable masking ability ($\Delta E_{00} < 2.8$), reaching excellent masking ability ($\Delta E_{00} < 1.1$) at 1.5 mm, except for 1.0 mm G-Br, which also demonstrated excellence. Post-opaquer, initially acceptable specimens improved to excellent masking ability across all shades and thicknesses (Table 2). Univariate analysis found no shade–thickness interaction, prompting separate analyses for comprehensive insights. In Figure 4, the impact of thickness on ΔE_{00} ($p < 0.0001$) exceeded shades ($p < 0.002$), with decreasing ΔE_{00} as thickness increased, indicating enhanced masking ability. Analysis revealed that 0.5 mm G-DP demonstrated the lowest masking ability, while 2.0 mm G-Br demonstrated the highest. The Bonferroni test confirmed significant ΔE_{00} differences between groups for all thicknesses ($p < 0.0001$). Pairwise comparisons showed no significant difference between G-Br and G-LP at 0.5 mm ($p = 0.67$), and no statistical difference between G-Or and G-DP ($p = 1.00$), and G-DP and G-LP ($p = 1.00$), indicating similar masking abilities.

Table 1. The median CIEDE2000 values of all shades and thicknesses for the gingiva-colored giomer (obtained without using an opaquer).

Shade	Thickness (mm)	L*			a*			b*		
		Black	White	Gingiva-Colored Giomer	Black	White	Gingiva-Colored Giomer	Black	White	Gingiva-Colored Giomer
G-Br	0.5	50.3	54.7	48.9	13.1	15.1	14.8	26.0	31.6	30.0
	1.0	50.4	53.4	50.3	16.9	18.6	17.8	33.0	35.4	34.6
	1.5	48.4	49.8	48.3	18.2	19.6	18.7	33.5	35.1	33.9
	2.0	46.2	47.1	46.5	18.5	19.4	18.7	33.7	34.5	33.9
G-Or	0.5	52.1	59.2	53.9	15.6	17.4	17.2	37.3	40.6	39.0
	1.0	55.6	60.0	57.0	18.6	20.8	20.1	41.7	45.6	43.5
	1.5	54.8	57.0	55.4	21.8	23.6	22.6	44.5	46.1	45.0
	2.0	55.5	56.9	55.7	22.9	24.8	23.7	44.9	46.5	45.8
G-DP	0.5	50.6	58.8	52.9	16.6	18.3	18.4	33.3	36.7	35.6
	1.0	52.3	57.1	54.0	20.6	22.7	21.8	39.4	43.0	40.8
	1.5	53.2	55.2	53.9	24.8	26.8	25.5	44.0	45.9	44.4
	2.0	52.9	54.4	53.2	24.7	26.1	25.3	42.3	42.7	43.2
G-LP	0.5	61.4	67.7	63.6	11.1	12.4	12.4	28.0	30.8	29.9
	1.0	65.6	68.7	67.0	14.4	16.0	15.5	33.7	36.1	34.9
	1.5	66.2	68.1	66.6	16.0	17.8	17.2	35.0	37.2	36.4
	2.0	66.9	68.0	67.3	17.3	18.8	18.0	36.1	37.7	36.9
G-V	0.5	52.5	53.2	52.5	11.6	12.6	11.8	12.9	13.9	12.9
	1.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	1.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	2.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

G-V color difference beyond 1.0 mm was unobtainable and represented as N/A (not applicable).

After opaquer application, ΔE_{00} values for 1.0 mm, 1.5 mm, and 2.0 mm showed no significant difference ($p < 0.05$). However, 0.5 mm ΔE_{00} remained significantly different from the others. Statistical analysis revealed no significant ΔE_{00} differences ($p > 0.05$) among shades. Overall, thicker layers reduced ΔE_{00}, indicating improved masking ability. Opaquer further decreased ΔE_{00} for all thicknesses and shades (see Figure 5).

Table 2. The median values and interquartile range (IQR) of ΔE_{00} of all shades and thicknesses, without and with opaquer.

	Thickness	ΔE_{00} Median of Shades (IQR)				
		G-Br	**G-Or**	**G-DP**	**G-LP**	**G-V**
Without Opaquer	0.5	2.2 * (1.4)	2.2 * (0.5)	2.4 * (1.7)	2.0 * (0.5)	1.5 * (0.6)
	1.0	1.1 ** (0.4)	1.7 * (0.7)	1.8 * 0.5)	1.2 * (0.6)	N/A
	1.5	0.8 ** (0.4)	0.9 ** (0.3)	0.7 ** (0.4)	0.9 ** (0.2)	N/A
	2.0	0.7 ** (0.4)	0.8 ** (0.4)	0.7 ** (0.2)	0.7 ** (0.3)	N/A
With Opaquer	0.5 (O)	0.9 ** (0.9)	0.7 ** (0.3)	0.9 ** (1.1)	0.8 ** (0.9)	N/A
	1.0 (O)	0.7 ** (0.8)	0.7 ** (0.4)	0.8 ** (0.4)	0.7 ** (0.6)	N/A
	1.5 (O)	0.7 ** (0.3)	0.8 ** (0.3)	0.6 ** (0.2)	0.6 ** (0.2)	N/A
	2.0 (O)	1.0 ** (0.5)	0.6 ** (0.6)	0.6 ** (0.3)	0.5 ** (0.2)	N/A

* Indicates acceptable masking ability (ΔE_{00} < 2.8) and ** indicates excellent masking ability (ΔE_{00} < 1.1). G-V color difference beyond 1.0 mm was unobtainable and represented as N/A (not applicable).

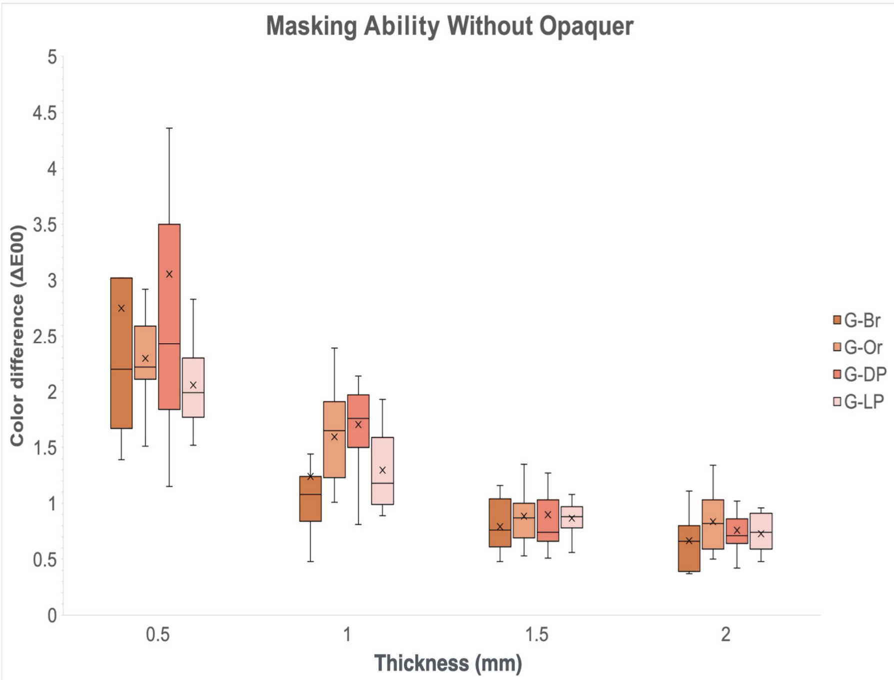

Figure 4. The ΔE_{00} median values for masking ability of specimens without opaquer between black background and giomer-itself background.

TP_{00} values, reflecting translucency in gingiva-colored giomers, were compared between black and white backgrounds for each specimen (Table 3). A notable inverse correlation between TP_{00} trend and masking ability emerged, revealing a decrease in TP_{00} as thickness increased (Figure 6). Univariate rank analysis identified an interaction between shades and thicknesses, leading to a combined analysis. Pairwise comparisons highlighted distinctions among shades at different thicknesses. Notably, at 0.5 mm, G-Br demonstrated the lowest TP_{00}, and G-DP the highest, with significant differences in most shades. The observed patterns persisted at varying thicknesses, emphasizing the nuanced translucency relationships between shades.

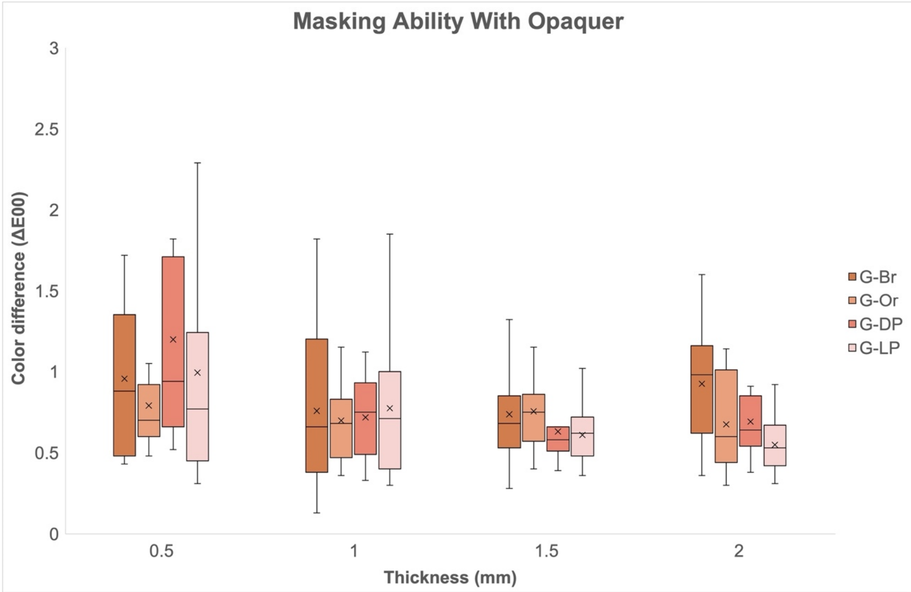

Figure 5. The ΔE_{00} median values for masking ability of specimens with opaquer between black background and the giomer-itself background.

Table 3. The median values and interquartile range (IQR) of TP_{00} of all shades and thicknesses, without and with opaquer.

	Thickness	TP_{00} Median of Shades (IQR)				
		G-Br	G-Or	G-DP	G-LP	G-V
Without Opaquer	0.5	5.0 (1.5)	6.7 (2.1)	7.3 (2.0)	5.3 (1.1)	10.7 (2.4)
	1.0	3.3 (1.2)	4.3 (1.2)	4.7 (0.8)	2.7 (0.7)	N/A
	1.5	1.8 (0.8)	2.5 (0.6)	2.1 (0.3)	2.0 (0.4)	N/A
	2.0	3.3 (1.2)	1.8 (0.5)	1.5 (0.6)	1.3 (0.2)	N/A
With Opaquer	0.5	0.8 (0.3)	0.7 (0.8)	1.7 (0.9)	1.2 (0.7)	N/A
	1.0	0.8 (0.4)	1.2 (0.4)	1.0 (0.4)	0.6 (0.3)	N/A
	1.5	0.7 (0.5)	0.7 (0.3)	0.6 (0.2)	0.7 (0.5)	N/A
	2.0	0.9 (0.5)	0.8 (0.3)	0.7 (0.2)	0.6 (0.2)	N/A

G-V color difference beyond 1.0 mm was unobtainable and represented as N/A (not applicable).

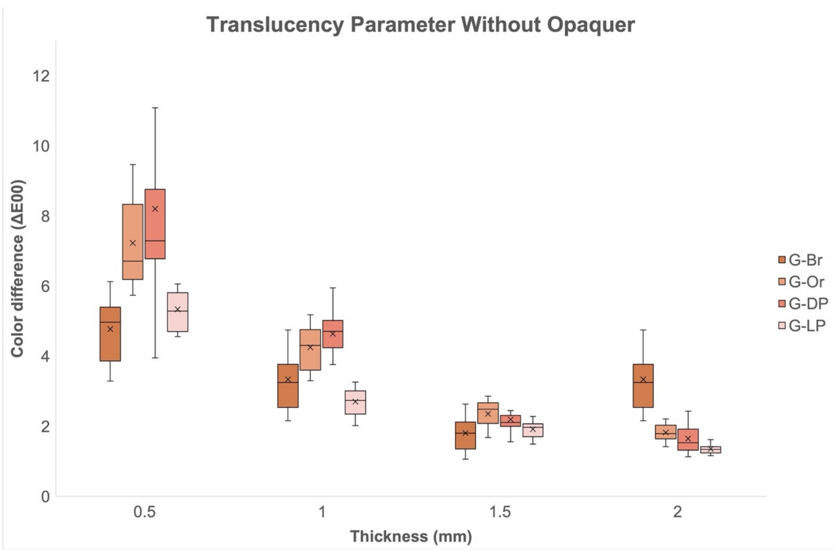

Figure 6. The TP_{00} median values for specimens without opaquer were compared between black and white backgrounds.

Following opaquer application, overall results revealed decreased translucency with increased thickness in all shades, except G-Or and G-DP (Figure 7). Intra-thickness shade comparisons showed no statistically significant patterns. The Wilcoxon signed-rank test compared ΔE_{00} between specimens with and without opaquer, revealing significant differences in all thicknesses, except for G-Br at 1.5 mm, G-Or at 1.5 mm and 2.0 mm, and G-DP at 2.0 mm. After opaquer application, the average ΔE_{00} decreased in all shades and thicknesses. TP_{00} also decreased significantly.

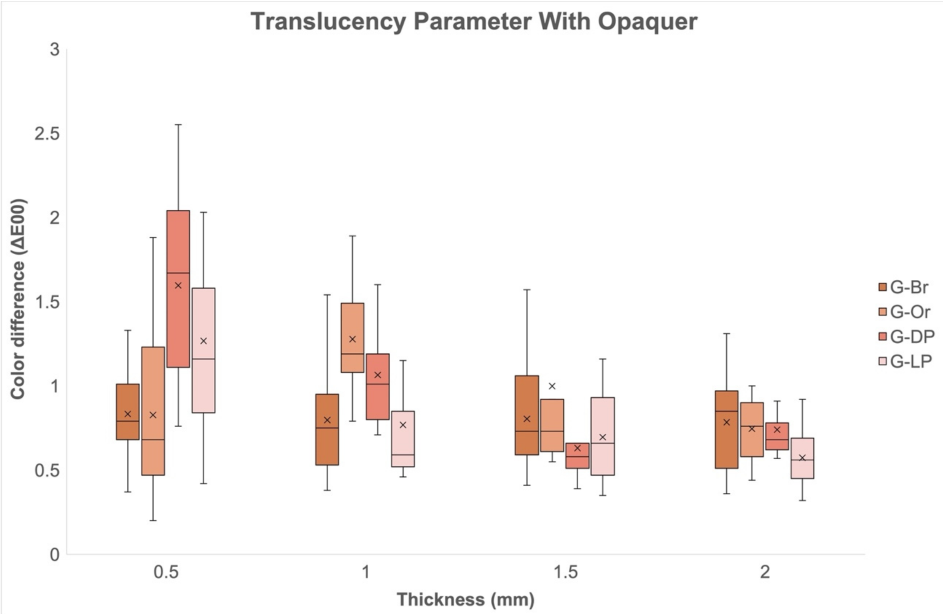

Figure 7. The TP_{00} median values for specimens with opaquer were compared between black and white backgrounds.

4. Discussion

The accurate matching of gingiva-colored restorations to the natural gingiva is crucial for enhancing the aesthetics of correcting gingiva-tooth defects and ensuring patient satisfaction. This study aimed to assess the masking ability and translucency, key factors influencing aesthetic appearance, of five direct gingival shades of restoration at four thicknesses. The investigation was designed to determine the impact of shades, thickness variations, and the presence of an opaquer on these two critical parameters. The results demonstrated that these factors directly contribute differently to the color coordinates and overall appearance of gingiva-colored restorations. Consequently, both null hypotheses of this study were rejected. These findings highlight that variations in translucency and masking ability significantly influence the selection of restorative materials, as these properties are critical for achieving aesthetic and functional outcomes in clinical applications.

The present study limited the maximum thickness of gingiva-colored restorations to 2.0 mm, based on earlier research conducted on tooth-colored composite resin [31,35,41], despite the lack of specific research addressing the masking ability and translucency of gingiva-colored giomers. Previous studies suggested that an opaque-shade resin composite with a thickness between 1.5 and 2.0 mm effectively hides the underlying background while keeping ΔE_{00} within the imperceptible range ($\Delta E^* < 2.0$) [29]. Notably, a recent examination of optical properties found that 1.0 mm thickness of flowable giomers was not enough to conceal a C3 shaded composite resin background, mimicking a discolored cavity [31]. Another study emphasized the significant impact of background color on the appearance of gingiva-colored restorations, including Beautifil II gingiva [34]. It revealed that a 1.0 mm specimen exhibited an unacceptable color difference between air and the tooth-colored background, whereas a 2 mm specimen demonstrated an acceptable color difference (ΔE* < 2.8). Consequently, the current study selected four thicknesses (0.5, 1.0, 1.5, and 2.0 mm) to examine changes in color coordinates (L*, a*, b*) in relation to shades and backgrounds. Additionally, a 10 mm diameter was chosen for the specimens to ensure that it covers the size of the analyzing tip of spectrophotometer (VITA Easyshade, Germany). Note that this specimen has a different shape and is larger than those clinically observed in restoration of cervical lesions caused by abrasion or abfraction [28]. Traditionally, color difference evaluation (CIELab or CIEDE2000) has been based on flat 2D color samples. However, the visual perception of color in 3D samples is more complex due to factors such as shape, size, light field structure, translucency, gloss, and shadow. In particular, glossy samples with different shapes and sizes can result in varied visual perceptions [42]. Therefore, the values obtained from the present study were based on in vitro conditions and may not directly apply to clinical situations [41].

The present study builds on prior research by offering a focused examination of the translucency and masking abilities of gingiva-colored giomers, emphasizing their clinical applicability for gingival restorations. Unlike earlier works that broadly evaluated the optical properties of composites and giomers, this investigation provides material-specific insights by assessing five distinct shades and multiple thicknesses under clinically relevant conditions. For instance, while Darabi et al. (2014) [31] and Rusnac et al. (2021) [32] demonstrated the importance of thickness and background color in masking ability, their studies primarily focused on tooth-colored composites. In contrast, the present findings reveal that gingiva-colored giomers achieve acceptable masking ability at a minimal thickness of 0.5 mm and excellent masking ability at 1.5 mm, even against challenging black backgrounds. This performance surpasses that of conventional composites, which often require greater thickness to achieve comparable results.

The color measurements for all 255 samples in this study were carried out using the VITA Easyshade spectrophotometer, a clinical device primarily designed for operation in "tooth mode". While this instrument is generally not recommended for in vitro testing due to its limitations in accuracy and precision [43], VITA Easyshade remains sufficiently reliable and precise for applications in dental practice. Specifically, it has demonstrated utility in studies examining tooth color variations [44] and, to a lesser extent, in the assessment of gingiva-colored giomers [45], as also evidenced in the current study's findings. As mentioned earlier, the spectrophotometer has a measurement range of 400–700 nm [46]. During the color measurement of G-V shade specimens in the present study, an error statement "The shade measured is outside of the measurement range" appeared on the screen, and the L*, a*, b* value was not presented. This may be due to the fact that the color violet has a wavelength range of 385–425 nm [47], rendering the shade G-V undetectable by the spectrophotometer. Furthermore, a study [33] evaluating color-measuring devices reported that VITA Easyshade is capable of measuring color within the range of the VITAPAN Classical shade guide. However, when measuring color with a value above 7 and a hue ranging from 7.5 YR to 10 YR, the ΔE value was unacceptable. This indicates that the spectrophotometer has limitations and may not measure colors beyond the typical tooth color range [48].

Based on the results of the present study, an increase in thickness and the presence of an opaquer lead to an improvement in masking ability (resulting in a decrease in ΔE_{00}) and a reduction in translucency (resulting in a decrease in TP_{00}). An exponential relation was observed between thicknesses and shades for both ΔE_{00} and TP_{00}, as depicted in Figures 4 and 6. These findings associate with previous studies [29,32,33,41]. A high ΔE_{00} indicates a lower capacity to mask the respective background. When comparing ΔE_{00} to the 50:50% perceptibility and acceptability threshold for gingiva, excellent masking ability is indicated when the ΔE_{00} value is below 1.1. This suggests that the color difference is detectable for 50% of the observers. A ΔE_{00} value between PT and AT ($1.1 \leq \Delta E_{00} \leq 2.8$) represents an acceptable masking ability, meaning that 50% of observers would consider the color difference to be clinically unacceptable. A ΔE_{00} value above AT ($\Delta E_{00} > 2.8$) represents an unacceptable masking ability [49]. Moreover, the application of opaquer resulted in decreased translucency with increased thickness for all shades, except G-Or and G-DP, and no statistically significant patterns were observed in intra-thickness shade comparisons. The presence of opaquer suggested that heightened thickness does not consistently reduce translucency. While masking ability improved with the opaquer, translucency decreased. For shades within 1.5 mm and 2.0 mm, no significant differences indicated similar translucency. Pre-opaquer, G-Br and G-LP, as well as G-Or and G-DP, exhibited analogous masking trends, but this translucency pattern changed post-opaquer application. The findings of the present study align with earlier research [33,41], validating that an opaque-shade composite resin thickness between 1.0 and 2.0 mm, with a cut-off at $\Delta Eab < 3.3$ [32], is essential for effectively masking a black background color [41]. Additionally, it supports the notion that a 2 mm thickness is more effective than 1 mm for shade matching, especially when considering dark-background effects within the range of $\Delta Eab < 2.0$ [33]. Indeed, based on the 50:50% perceptibility and acceptability thresholds for gingiva-colored giomers, the minimum thickness of 0.5 mm was required to mask a black background to achieve an acceptable masking ability, while 1.0–1.5 mm was required to achieve an excellent masking ability. While the results demonstrate that a 0.5 mm thickness provides acceptable masking ability, the translucency parameter (TP_{00}) values at this thickness are notably lower than those of human gingiva, as documented in previous studies [50]. This reduction in translucency may affect the material's ability to blend seamlessly with surrounding tissues, particularly in lighter gingival tones or highly aesthetic areas. To address this, clinicians may consider increasing the thickness selectively in visually critical areas or combining the gingiva-colored giomer with more translucent materials using layering techniques to achieve better aesthetic integration.

The outcomes of the current study exhibit subtle differences from previous reports [31,35,41]. In this investigation, gingiva-colored giomers demonstrated a moderately heightened masking ability, possibly attributed to distinctions in composition—specifically, types, sizes, and amounts of inorganic fillers—compared to the tooth-colored composite resin in prior studies [31,35,41]. Masking ability is anticipated to be affected by opacifiers, pigments, fillers, and various additives [35]. However, the results of this study align closely with recent research by Sen et al. (2024) [51], highlighting the critical interplay between restoration thickness, substrate color, and material composition in achieving optimal masking ability in gingiva-colored resin-based composites. Sen et al. demonstrated that lighter shades, such as light pink and orange, exhibited reduced masking performance, particularly over darker substrates, unless a thickness of at least 2.0 mm was applied. Similarly, this study found that increasing thickness significantly enhances masking ability, with opaquer application further improving outcomes across all evaluated shades. Moreover, findings of our study on the translucency-reducing effect of thickness and opaquers complement Sen et al.'s results by demonstrating how these properties influence aesthetic outcomes. Future studies should integrate human visual assessments to validate instrumental findings and provide deeper insights into clinical acceptability thresholds. Moreover, another study highlighted that tooth-colored resin composite necessitated a thickness of 0.8–1.45 mm to mask an underlying discolored black cavity [52]. Contrarily, our study's findings suggested that a 0.5 mm thickness of gingiva-colored giomer effectively masked the underlying discolored cavity. This implies that addressing slightly shallow tooth defects with discoloration may require minimal preparation to eliminate the root dentin, facilitating a more conservative treatment approach for mild abrasion or gingival recession with root discoloration.

Our study further illustrates the correlation between increased thickness and reduced translucency, aligning with a prior investigation on composite resin translucency [53]. Both variations in thickness and the presence of pigments (opaquer) influence the translucency parameter (TP_{00}). Our findings suggest that heightened thickness and the use of an opaquer contribute to a decrease in TP_{00}. Macroscopic factors, including matrix composition, filler composition, filler content, minor pigment additions, and potentially all other chemical components, impact the translucency and color of aesthetic restorative materials [54]. Variations in these components likely explain the observed differences in color and translucency across materials. In a clinical setting, translucency parameters for peri-implant mucosa were reported at thicknesses of 0.5–1.0 mm, 1.0–1.5 mm, and 1.5–2.0 mm as 19.03, 11.97, and 10.20, respectively [50]. These values are higher than the TP_{00} values of gingiva-colored giomers reported in our study (Table 3). This suggests a possibility that the gingiva-colored giomer may have lower translucency than human gingiva, a consideration in clinical practice for mimicking natural gingival appearance. Therefore, additional studies on the implementation of gingiva-colored resin-based materials in clinical practice are warranted.

The results obtained from the current study reveal that most of the gingiva-colored giomers are consistent with the natural shades of gingiva within the ranges reported in previous studies [50,55,56] with the exception of the L* value for the G-LP shade and the b* value for all shades, as detailed in Table 1. The b* value registering higher than the normal gingiva in our findings may indicate a tendency for the gingival color of the giomer to lean more towards the yellow spectrum. However, drawing conclusive judgments about the material's appearance in a clinical context remains uncertain due to the myriad environmental factors that could influence the gingiva-colored materials' visual characteristics. Consequently, additional clinical studies are necessary to further explore this aspect. In fact, a study has reported noticeable translucency differences among different shades of the same brand, as well as among gingiva-colored materials labeled with the same shade but sourced from different brands [37]. These findings suggest that these variations could influence the clinician's choice of restorative material [37].

Nonetheless, while this study focused on masking ability and translucency, the color stability of resin-based materials is another critical factor that warrants further investigation. These materials are known to be susceptible to discoloration due to exposure to staining beverages [57] and smoke [58], which could compromise their long-term aesthetic performance. Future research should assess the impact of these environmental factors on color stability to provide a more comprehensive understanding of the clinical performance of gingiva-colored materials.

5. Conclusions

Within the limitation of this in vitro study, the following conclusions can be drawn:

1. The masking ability of the gingiva-colored giomer improved with increased thickness, as reflected by a decrease in ΔE_{00} values.
2. Translucency decreased with increasing thickness, resulting in a reduction in TP_{00} values.
3. The application of an opaquer further enhanced masking ability while reducing translucency. Notably, while distinct pre-opaquer trends were observed across shades, these trends were no longer evident for translucency after opaquer application.
4. Following opaquer application, similarities in masking ability and translucency were observed between certain shades, specifically G-Br and G-LP, and G-Or and G-DP, with some exceptions for translucency differences.

5. The gingiva-colored giomer demonstrated acceptable masking ability at a minimum thickness of 0.5 mm and excellent masking ability at a minimum thickness of 1.0 mm.

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