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RESEARCH ARTICLE

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Effect of thickness, translucency, and substrates on the masking ability of a polymer-infiltrated ceramic-network material

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Abstract

Objective: The aim of this in vitro study is to evaluate the masking ability of polymer-infiltrated ceramic-network materials (PICN) with different translucencies and thicknesses on multiple types of substrates.

Materials and Methods: Ceramic samples were prepared of VITA ENAMIC blocks in two different translucencies (2M2-T, 2M2-HT) in a thickness range of 0.5–2.5 mm (±0.05 mm). Layered specimens were obtained using composite substrates in nine shades and transparent try-in paste. Spectral reflectance of specimens was measured using a Konica Minolta CM-3720d spectrophotometer and D65 standard illumination. CIEDE2000 color difference (ΔE_{00}) between two samples was evaluated using 50%:50% perceptibility and acceptability thresholds. Specular component of the reflection was examined with Specular Component Excluded (SCE) and Included (SCI) settings. Statistical evaluation was performed by linear regression analysis, Kruskal–Wallis test, and multiplicative effect analysis.

Results: An increase in thickness of 0.5 mm reduces ΔE_{00} of HT samples to 73.5%, of *T* samples to 60.5% ($p < 0.0001$). Five substrates with HT specimens, and three substrates with *T* specimens had significantly different results from average ($p < 0.05$). There is a significant difference between SCE and SCI data depending on the wavelength ($p < 0.0001$).

Conclusions: Masking ability of PICN materials is influenced by the thickness and translucency of the ceramic, and by the substrate. Reflection of the examined PICN material is characterized by both diffuse and specular reflection.

Clinical Significance: Although PICN materials have been available on the market for 10 years now, there is a lack of information regarding their masking ability. Acquiring in-depth data and thereby practical experience of the factors affecting the esthetics of PICN materials is essential for creating perfectly lifelike restorations.

KEYWORDS
color difference, dental ceramic, masking ability, PICN material, spectrophotometer, substrate, thickness

1 | INTRODUCTION

Esthetic dentistry has undergone enormous development in recent decades thanks to digital technology and modern materials.[1–3] The goal of digital dentistry has been clear from the beginning: to achieve planable, reproducible quality through a process consisting of the fewest possible steps.[4] The widespread use of intraoral and laboratory scanners and the rise of CAD/CAM technology define today's dentistry,[5,6] and its success has resulted in the continuous development of available materials.[7] Until the appearance of hybrid ceramics, metal-free materials that could be processed by milling and were suitable for making permanent dental restorations could basically be classified into two groups: ceramics and composites.[8] The main goal of developing hybrid ceramics was to create a material that combines the beneficial properties of ceramic and composite materials and is similar in mechanical and optical characteristics to natural tooth tissues. The two main groups of hybrid ceramics are resin nanoceramics (RNC) and polymer-infiltrated ceramic-network materials (PICN). VITA ENAMIC (VITA Zahnfabrik, Bad Säckingen, Germany) is the only PICN on the market since its release in 2013.[9] Its structure consists of a sintered, porous ceramic matrix (86% in weight) and an infiltrated polymer matrix (14% in weight), which is polymerized at high temperature and high pressure during its production.[10] A big advantage is that the material does not require burning or sintering after milling, so it can be an ideal choice for chair-side dentistry. According to the manufacturer the indications of PICN are single tooth restorations: anterior and posterior crowns (implant-supported as well), inlays, onlays, partial crowns, table tops, veneers.[11] Several studies concluded that properties of PICN materials are close to those of dentin and enamel,[8,12–14] it causes less abrasion on antagonistic teeth surfaces than other dental ceramic materials,[15] but its hardness is greater than that of composites, therefore it is more wear-resistant.[9,11,16]

In the case of metal-free restorations, in addition to the mechanical properties, the similarity to natural tooth tissues and the esthetic, predictable result are the decisive factors. Requirements and expectations of both patients and dentists are constantly increasing the focus of researchers to examine the optical properties of the ceramic materials used.[17] In the case of materials with translucent properties, the appearance of the restoration is not determined solely by its material, but by everything that is located behind or under it. In the case of all-ceramic systems, several studies have examined factors affecting the esthetics of the final restoration, such as the color of the abutment, the thickness and translucency of the ceramic, and the color and layer thickness of the luting cement.[18–30] During the examination of lithium-disilicate glass ceramics, it was found that the color of the abutment, the thickness of the ceramic and the color of the cement significantly influence the color of the restoration.[18,20] Regarding the final appearance of monolithic zirconia restorations, studies emphasize the effect of abutment color, ceramic thickness, and their combined effect.[19,22,23] A research that compared the masking ability of monolithic zirconias and zirconia-reinforced lithium-silicate glass ceramics with different layer thicknesses confirmed the influence of layer thickness and abutment color in addition to the better masking ability of monolithic zirconias.[24] Although PICN hybrid ceramics have been available on the market for 10 years, there is a lack of information regarding their masking ability.[26–31]

Color perception is greatly influenced by the surface of the ceramic, its reflective properties, beyond the aforementioned parameters. Light reflection can be specular, diffuse, or a mixture of these in different proportions.[32] Since spectrophotometers determine the color of an object by illuminating it with its own light source and then measuring the reflection, the correct measurement setting is crucial during the procedure. Laboratory spectrophotometers with integrating spheres are suitable for high-precision examination of various dental materials because, depending on the setting, they can include or exclude the specular component of the reflection.

The aim of this in vitro study is to evaluate the masking ability of PICN hybrid ceramics with different translucencies and layer thicknesses on multiple types of substrate materials.

The following hypotheses were tested in the study:

1. PICN reflects light only diffusely, without specular component.
2. Masking ability of PICN is not influenced by its layer thickness.
3. Masking ability of PICN is not influenced by the substrate.
4. Masking ability of PICN is not influenced by its translucency.

2 | MATERIALS AND METHODS

2.1 | Specimen preparation

Hybrid ceramic specimens were prepared of PICN material in 2M2 shade and two different translucencies (translucent 'T' and high translucent 'HT') (VITA ENAMIC, VITA Zahnfabrik, Bad Säckingen, Germany) for the in vitro examination. The rectangular ceramic specimens were made of prefabricated blocks with side lengths of 12 mm × 14 mm in 0.5 mm; 1.0 mm; 1.5 mm; 2.0 mm and 2.5 mm (±0.05 mm) layer thicknesses ($n = 30$). A diamond disc slicer (T-CG-04 01/2016, Tenzi, Hungary), a grinding machine (T-CG-05 04/2018, Tenzi, Hungary) and SiC800 grinding powder were used to cut and size the ceramic slices. Afterwards the specimens were polished with 0.5 µm cerium oxide powder. Thickness of the ceramic slices was validated with a digital micrometer (Mitutoyo, Kawasaki, Japan).

In addition to the ceramic specimens, substrate materials were also used to simulate the prepared abutment. Substrates were made from a special light-curing composite (IPS Natural Die Material, Ivoclar Vivadent, Vienna, Austria) in nine shades (ND1, ND2, ND3, ND4,

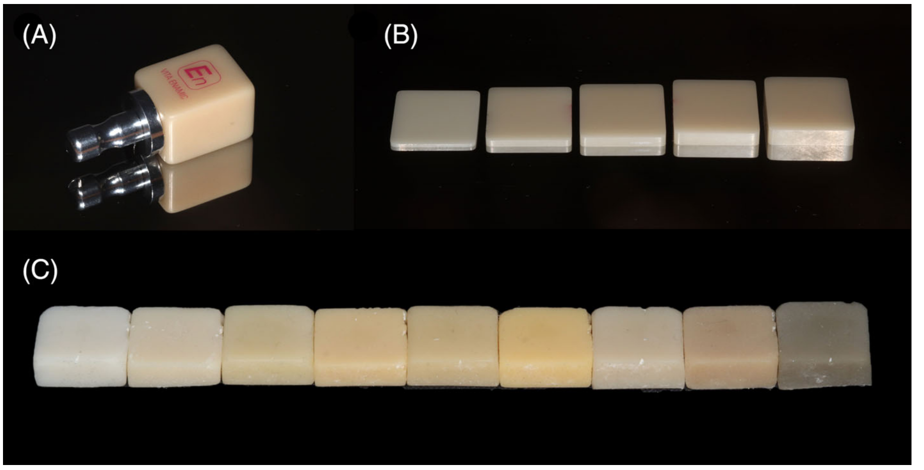

FIGURE 1 Ceramic and substrate materials used in the study. (A) PICN block; (B) Translucent PICN specimens in 0.5, 1.0, 1.5, 2.0, and 2.5 mm thicknesses (from left to right); (C) Light-curing composite substrates in 9 shades (ND1-ND9 from left to right).

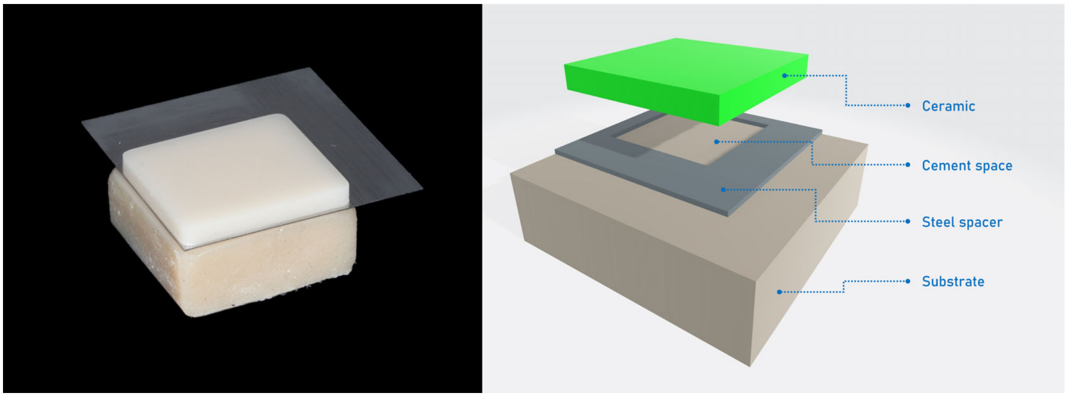

FIGURE 2 Layered specimen consisting of a ceramic sample, try-in paste, and substrate.

ND5, ND6, ND7, ND8, and ND9). Using transparent silicone impression material (Exaclear, GC, Tokyo, Japan) for production a template was made of a rectangular cuboid with side lengths of 20 mm × 20 mm × 8 mm. The silicone template was filled with composite substrate material and polymerization was carried out using a light polymerization unit (EyeVolution, Dreve ProDiMed, Unna, Germany). The surface of the substrates was polished according to the specifications of the manufacturer (Figure 1).

To fix the ceramic specimens on the substrates, transparent try-in paste was used in a layer thickness of 100 μm (Variolink Esthetic Try-In Paste [Neutral], Ivoclar Vivadent, Vienna, Austria). In order to ensure that the try-in paste layer thickness is standard a 100 μm thick steel spacer and an automatic pipette were used (Figure 2).

Each PICN sample was combined with all the substrates, so a total of 90 types of layered specimens were examined.

2.2 | Spectrophotometric measurements

Spectrophotometric measurements were performed using a Konica Minolta CM-3720d (Konica Minolta, Tokyo, Japan) spectrophotometer in a wavelength range from 360 to 740 nm at 10 nm pitch, with d/8 (diffuse illumination/8° viewing angle) measurement geometry.

$$\Delta E^*_{00} = \sqrt{\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'}{k_C S_C}\right)^2 + \left(\frac{\Delta H'}{k_H S_H}\right)^2 + R_T \frac{\Delta C'}{k_C S_C} \frac{\Delta H'}{k_H S_H}}$$

FIGURE 3 CIEDE2000 formula.

The device has a 6-inch barium sulfate coated integrating sphere with superior optical characteristics, and can measure the spectral reflectance of the samples, from which it calculates the L^*, a^*, b^* values according to D65 standard illumination. Three measurements were performed without replacement, and the results were averaged. Color difference (ΔE_{00}) between two samples was calculated using the CIEDE2000 formula (valid since 2000)[33] recommended by the International Commission on Illumination (Commission Internationale de l'Éclairage, CIE),[34] as it had been proved to provide higher degree of fit to visual perception than CIE76 (Figure 3).[35] $\Delta L'$, $\Delta C'$, and $\Delta H'$ parameters in the formula are differences in lightness, chroma, and hue values of two samples, R_T is the hue rotation term applied to weighted hue and chroma differences. S_L, S_C, and S_H are weighting factors, parametric factors k_L, k_C, and k_H are correction terms for variation in experimental conditions.[34] $PT_{50\%:50\%} = 0.8$ (50%:50% perceptibility threshold) and $AT_{50\%:50\%} = 1.8$ (50:50% acceptability threshold) ΔE_{00} values were applied to evaluate color difference results.[36,37]

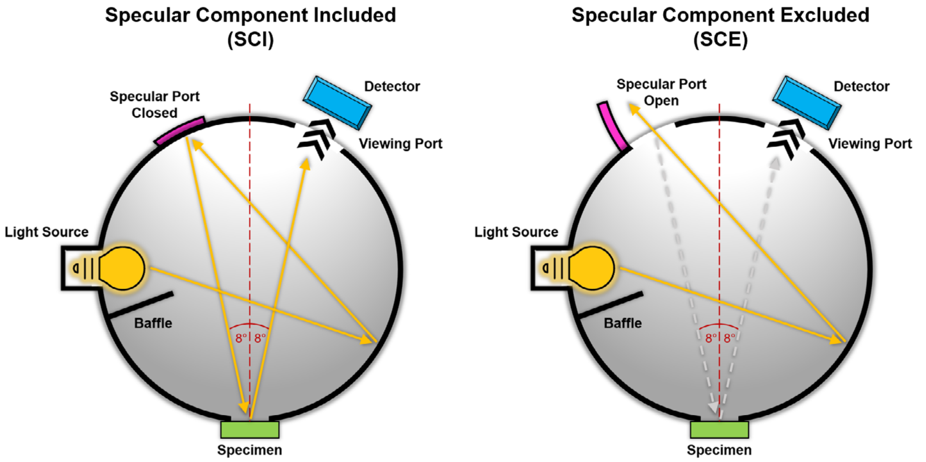

FIGURE 4 Schematic figure of the spectrophotometer's integrating sphere with specular component included (SCI) and specular component excluded (SCE) settings.

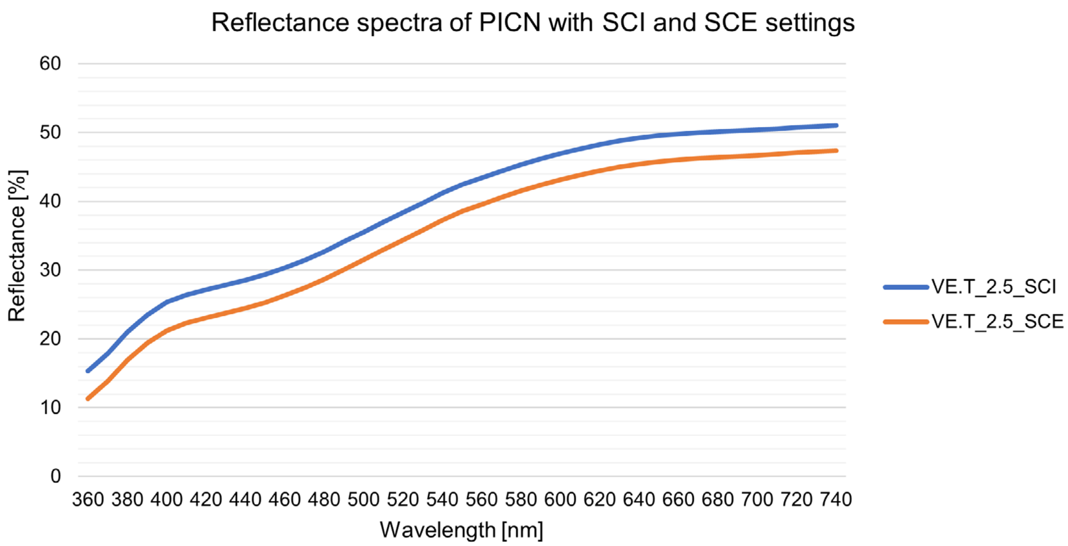

FIGURE 5 Reflectance spectra of translucent PICN sample of 2.5 mm thickness with specular component excluded (SCE) and specular component included (SCI) settings of the spectrophotometer.

1. The integrating sphere has two ports: the viewing port and the specular port (Figure 4). Detectors measuring reflected light are located behind the viewing port, while the specular port can be opened or closed depending on the setting. In open setting (Specular Component Excluded, SCE) the light is not reflected onto the surface of the sample from the area of the sphere corresponding to the port, but leaves the integrating sphere, therefore the component of the reflection that would be specularly reflected from the sample does not even reach it, and is excluded from the measurement. So, if our sample was a mirror the reflection of which is 100% specular, the spectrophotometer would measure the object's color as black. If we use the closed setting of the specular port (Specular Component Included, SCI), the specular component of the reflection would be reflected from the inner surface of the sphere and would reach the sample, making it detectable to the spectrophotometer. With SCI setting, the real color data of the sample can be measured regardless of the surface properties. To examine the specular component of the reflection, spectral reflectance of the 2.5 mm thick *T* ceramic specimen was measured using SCI and SCE settings of the spectrophotometer. To evaluate the difference between the two settings, obtained reflectance spectra were compared with each other, and statistical evaluation was performed by linear regression analysis ($p < 0.05$).

2., 3., 4. The effect of translucency, layer thickness and substrate on the masking ability of PICN were examined using layered specimens. To demonstrate the masking ability, color differences (ΔE_{00}) were calculated between individual layered samples and specific reference samples. The results of layered specimens containing T ceramic were compared with the results of the *T* ceramic block (as a target color), and the results of layered specimens containing HT ceramic were compared with the results of the HT ceramic block. The analysis of the distribution of ΔE_{00} values was performed using the Kruskal–Wallis test, and the effect of layer thickness and substrate on the masking ability was analyzed using multiplicative effect analysis ($p < 0.05$).

3 | RESULTS

1. Regarding the specular component of the reflection of PICN, SCE data were respectively below SCI values (Figures 5, 6). In the case

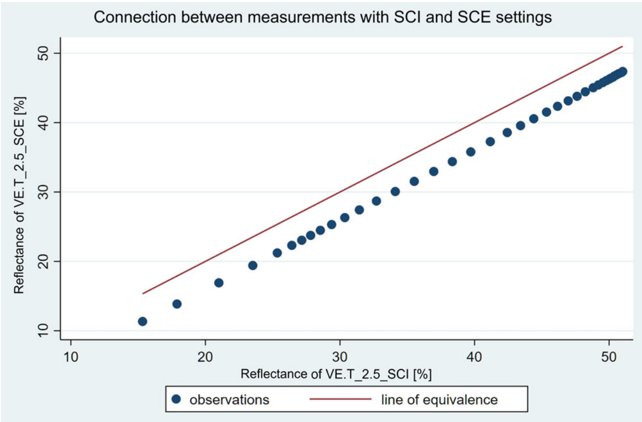

FIGURE 6 Relationship of reflectance measurements of the PICN sample with specular component excluded (SCE) and specular component included (SCI) settings.

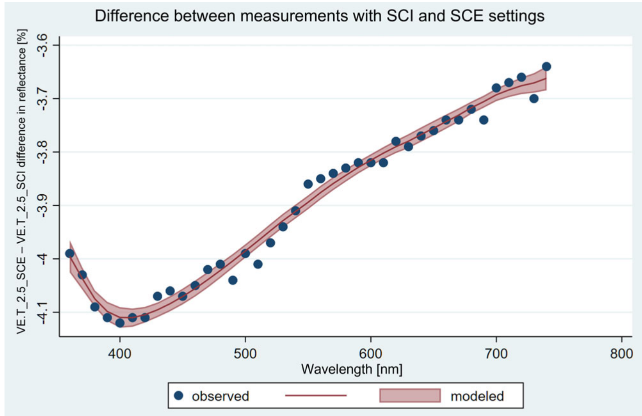

FIGURE 7 Modeled U-shaped relationship of difference between measurements with specular component excluded (SCE) and specular component included (SCI) settings and wavelength obtained by linear regression analysis.

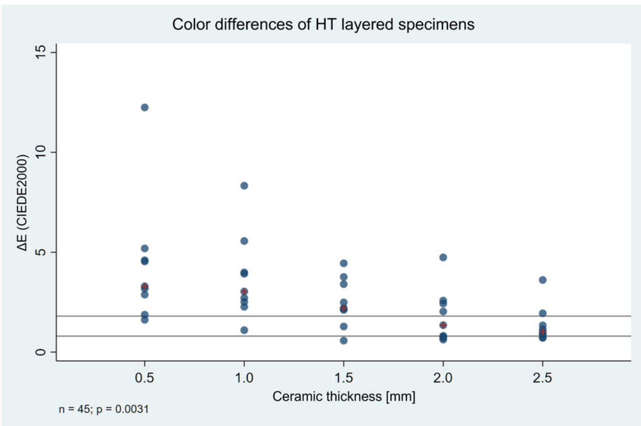

FIGURE 8 Dependence of ΔE_{00} values of HT layered specimens on the ceramic thickness. Reference sample: HT block. The median of each group is indicated by a red cross. $PT_{50\%:50\%} = 0.8$ and $AT_{50\%:50\%} = 1.8$ are marked on the diagram.

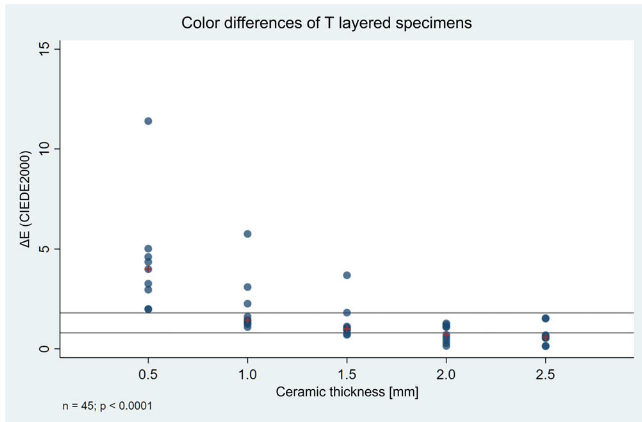

FIGURE 9 Dependence of ΔE_{00} values of *T* layered specimens on the ceramic thickness. Reference sample: *T* block. The median of each group is indicated by a red cross. $PT_{50\%:50\%} = 0.8$ and $AT_{50\%:50\%} = 1.8$ are marked on the diagram.

of a match, the blue data points ('observations') would fit on the red line of equivalence. At the same time, in the case of random fluctuation, they would be randomly located above or below it. The dependence of SCE-SCI differences on the wavelength was examined. A U-shaped relationship was found that can be modeled with linear regression; the shape fits the observation points very closely (Figure 7). There is a systematic difference between SCE and SCI data depending on the wavelength and the SCI value ($p < 0.0001$). The red area matches the 95% confidence interval of the modeled correlation.

2. The dependence of ΔE_{00} values of T and HT layered specimens on the ceramic thickness was evaluated (Figures 8, 9). Beside every layer thickness there is a group of nine observations corresponding to the measurements with the nine substrates. The median of each group is indicated by a red cross. Horizontal lines on the diagrams show the perceptibility ($PT_{50\%:50\%} = 0.8$) and acceptability ($AT_{50\%:50\%} = 1.8$) thresholds. Results of the multiplicative effect modeling are shown in Figures 10, 11. The nine panels detail the results for the nine substrates. Effect analysis revealed that in the examined range of 0.5–2.5 mm thickness, color difference changes according to a constant multiplier as the thickness increases. In the case of HT specimens, by increasing the thickness by 0.5 mm (if other factors that is, the substrate material, do not change), ΔE_{00} decreases to 0.735 times the initial value, in other words, to 73.5% of it, according to the estimate of the model. This relationship exists for all the samples the layer thicknesses of which differ by 0.5 mm. This effect is highly significant ($p < 0.0001$), and its 95% confidence interval ranges from 0.682 to 0.791. By increasing the thickness difference, its effect becomes stronger, for example, an increase of 1.5 mm thickness reduces the ΔE_{00} value by 0.735^3 times. In the case of *T* specimens, an increase in thickness of 0.5 mm reduces the ΔE_{00} value to 60.5%, $p < 0.0001$, its 95% confidence interval ranges from 0.553 to 0.661.

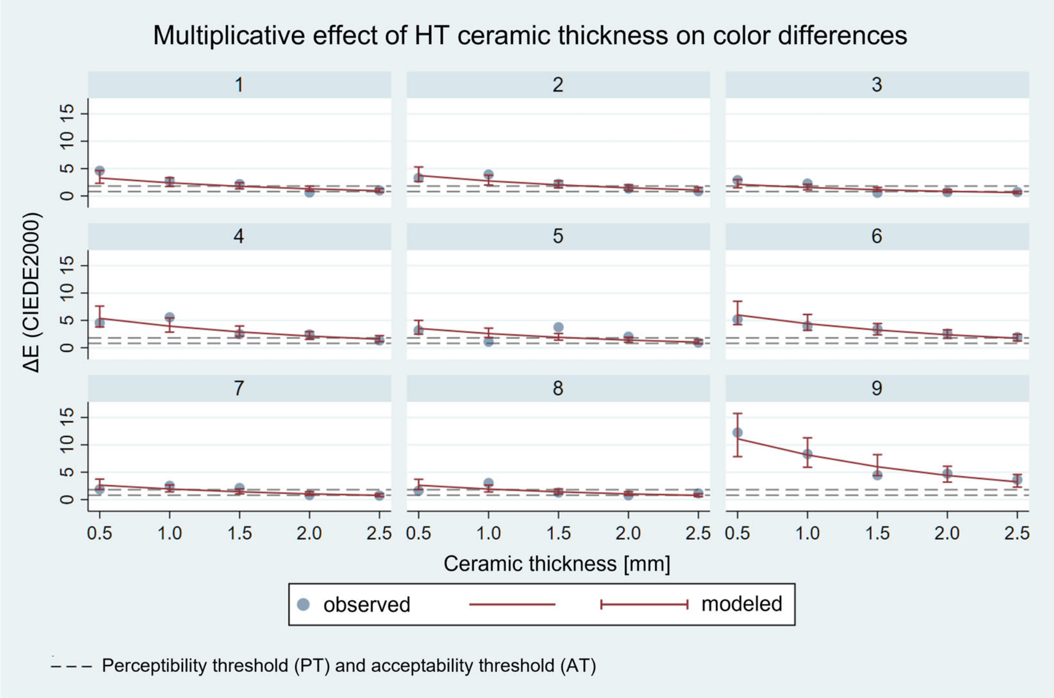

FIGURE 10 Modeled multiplicative effect of ceramic thickness on ΔE_{00} values of HT layered specimens. Each panel corresponds to the measurements of the indicated substrate.

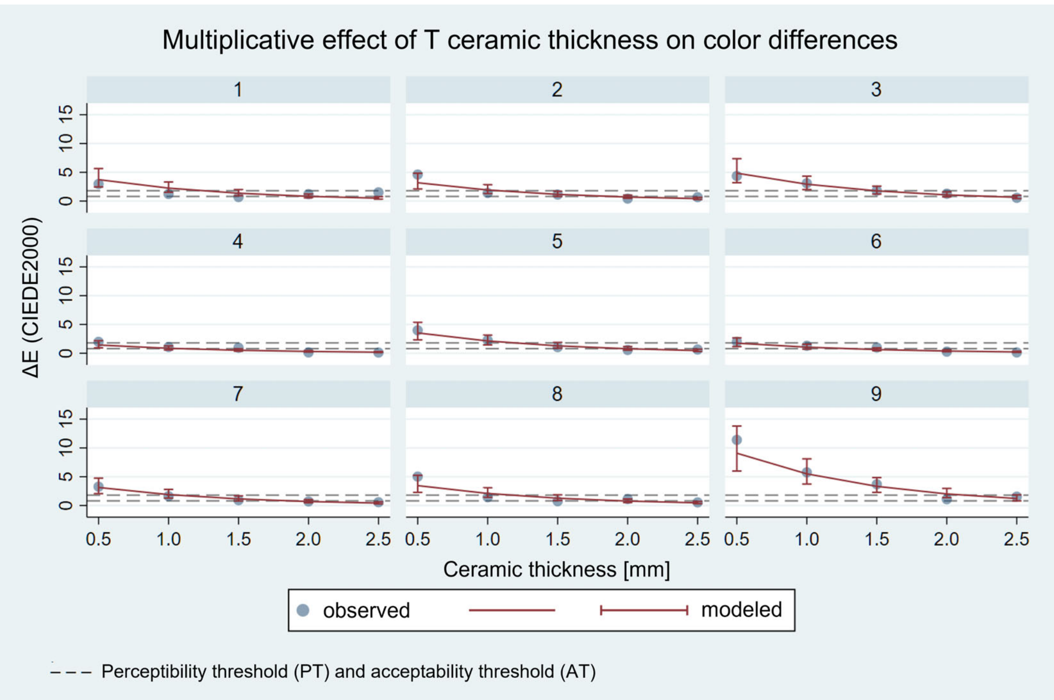

FIGURE 11 Modeled multiplicative effect of ceramic thickness on ΔE_{00} values of *T* layered specimens. Each panel corresponds to the measurements of the indicated substrate.

3. The dependence of ΔE_{00} values of *T* and HT layered specimens on the substrate material was evaluated (Figures 12, 13). Beside every substrate there is a group of five observations corresponding to the measurements with the five different ceramic thicknesses. The median of each group is indicated by a red cross. Horizontal lines on the diagrams show the perceptibility ($PT_{50\%:50\%} = 0.8$) and

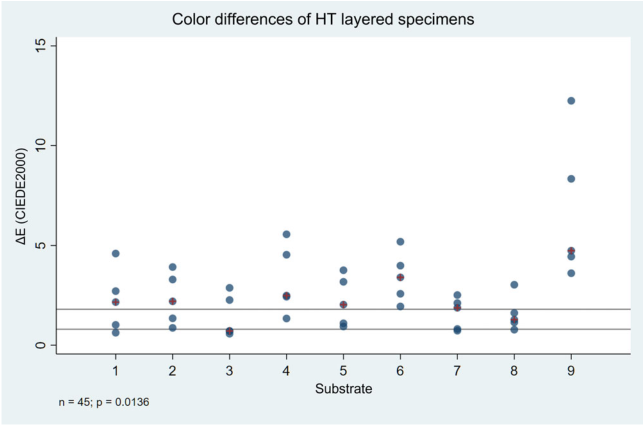

FIGURE 12 Dependence of ΔE_{00} values of HT layered specimens on the substrate. Reference sample: HT block. The median of each group is indicated by a red cross. $PT_{50\%:50\%} = 0.8$ and $AT_{50\%:50\%} = 1.8$ are marked on the diagram.

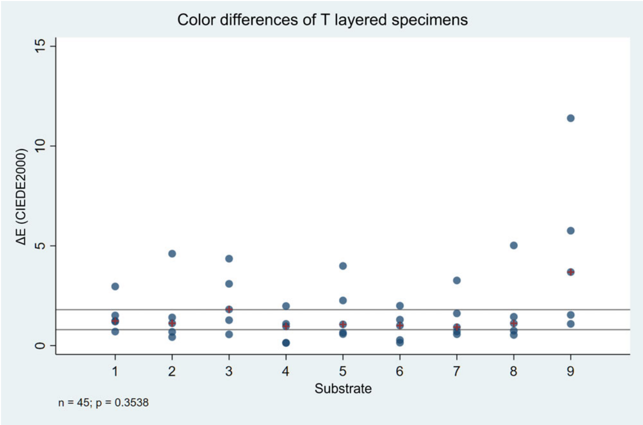

FIGURE 13 Dependence of ΔE_{00} values of T layered specimens on the substrate. Reference sample: *T* block. The median of each group is indicated by a red cross. $PT_{50\%:50\%} = 0.8$ and $AT_{50\%:50\%} = 1.8$ are marked on the diagram.

acceptability ($AT_{50\%:50\%} = 1.8$) thresholds. Results of the multiplicative effect analysis are shown in Figures 14, 15. The five panels detail the results for the five ceramic thicknesses. The effect of the substrate can be modeled with a constant multiplier as a characteristic of the material, which estimates the relationship between the average ΔE_{00} measured in the given ceramic thickness group and ΔE_{00} values of the layered specimens. The average color difference within the panels (green line) varies depending on the ceramic thickness. The effect can be modeled, is independent of the layer thickness, and is constant. In the diagrams, the positive or negative deviation from the mean value is significant ($p < 0.05$), if the modeled confidence intervals marked in red do not intersect the green line representing the mean value.

4. The effect of translucency was evaluated by comparing the results of *T* and HT materials. During the analysis of the effect of ceramic thickness it was found that with an increase in thickness of 0.5 mm the color difference from the reference sample decreases to 73.5% in the case of HT ceramic, and to 60.5% in the case of *T* ceramic. In Figures 14, 15 illustrating the effect of the substrate material group averages of results measured with ceramic thicknesses of 0.5 mm and 1.0 mm exceed $AT_{50\%:50\%}$ for both translucencies, but at a thickness of 1.5 mm *T* ceramic already falls below the acceptability threshold. Results of HT specimens with layer thicknesses of 2.0 mm and 2.5 mm fall in the range of 0.8–1.8 ΔE_{00}, while *T* ceramic shows group averages below $PT_{50\%:50\%}$ at this thickness.

4 | DISCUSSION

1. Regarding the specular component of the reflection of the PICN material, significant difference was found between the data measured with SCE and SCI settings, beyond the effect of random fluctuations. Thus, as specular reflection is a characteristic of the PICN material, the first hypothesis was rejected. Previous studies also agree on the glossy behavior of the surface of hybrid ceramics, of which resin nanoceramics have outstanding results, but PICN is also characterized by this property.[32,38]
2. The effect of the increase in layer thickness can already be seen in the diagrams of descriptive analysis of the results: group medians gradually decrease with the increase in thickness. Multiplicative effect analysis precisely showed that as the layer thickness of the ceramic increases, the color difference compared to the reference sample changes (decreases) according to a constant multiplier that is, the masking ability of the material increases. As this effect is highly significant ($p < 0.0001$) for both HT and *T* ceramics, the second hypothesis was also rejected. Previous studies do not provide such a numeric model of the effect of ceramic thickness on masking ability, but they clearly prove the phenomenon, and our results correlate with these findings.[26,27,30] Ruiz-López et al., during the examination of high translucent multi-color PICN materials, found that the lightness and chroma of the samples increases with thickening, but it does not show such a clear correlation with hue.[27] Alfouzan et al. examined the masking ability of hybrid ceramics, and a correlation was found between layer thickness and masking ability independent of ceramic type and background.[26] Pop-Ciutrila et al. investigated the translucency of leucite-reinforced glass ceramics, feldspar ceramics, zirconia-reinforced lithium-silicate glass ceramics and PICN ceramics with different layer thicknesses. For all materials tested, it was found that an increase in ceramic thickness causes a decrease in translucency that is, an increase in the masking ability of the material.[30]
3. As a result of the multiplicative effect analysis, it can be stated that the results of the layered specimens differ to group averages. Regarding the modeled confidence intervals, in the case of HT ceramics, substrate ND1, ND2, ND4, and ND5 are average, ND6 and ND9 are significantly worse than average, and ND3, ND7, and

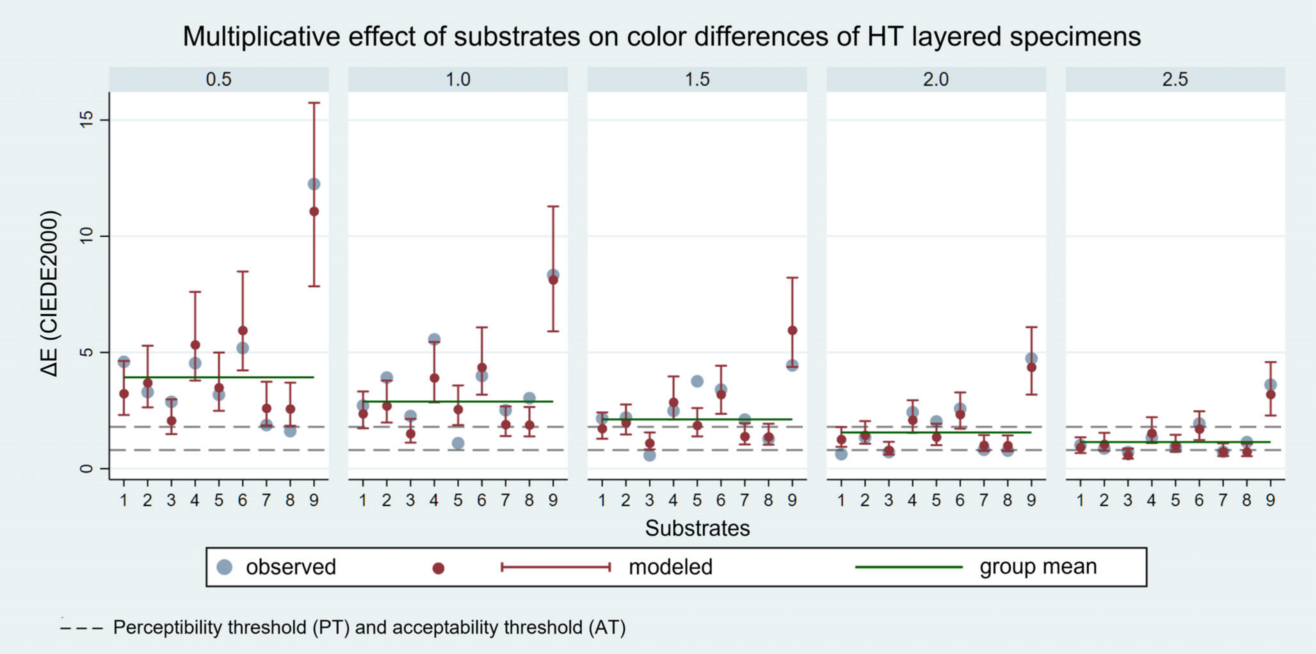

FIGURE 14 Modeled multiplicative effect of the substrate on ΔE_{00} values of HT layered specimens. Each panel corresponds to the measurements of the indicated ceramic thickness. Group averages are indicated by green lines.

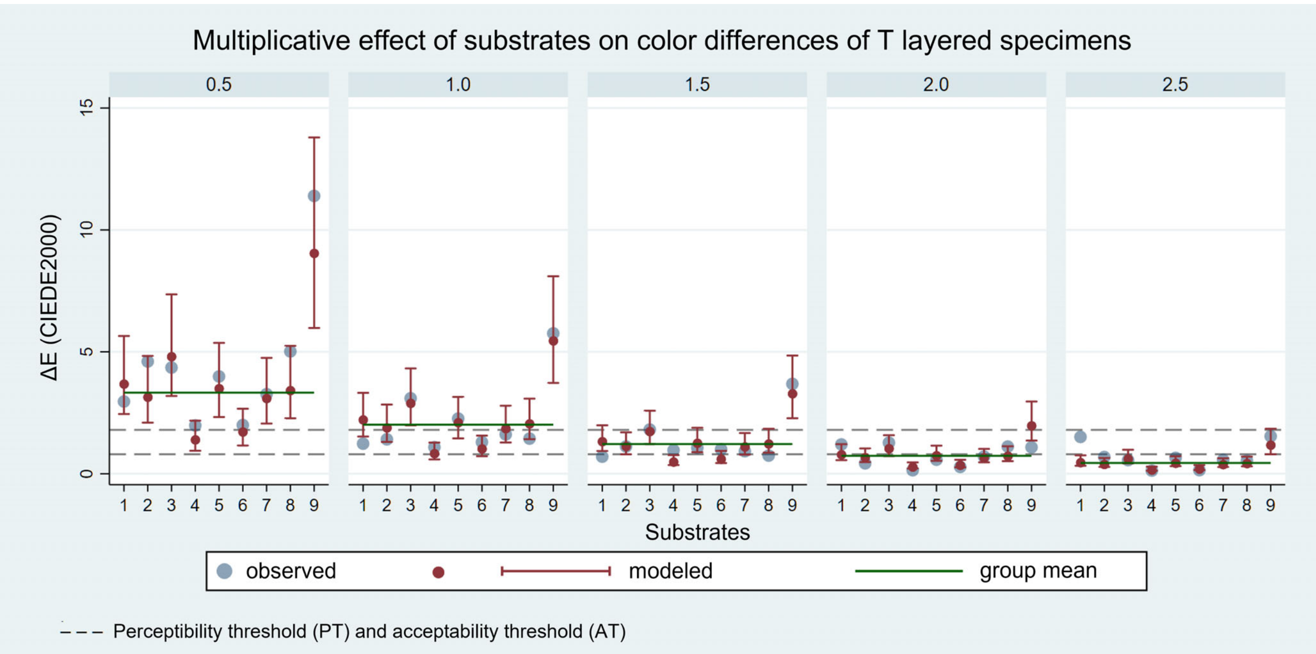

FIGURE 15 Modeled multiplicative effect of the substrate on ΔE_{00} values of *T* layered specimens. Each panel corresponds to the measurements of the indicated ceramic thickness. Group averages are indicated by green lines.

ND8 are significantly better. In the case of T ceramics, ND1, ND2, ND3, ND5, ND7, and ND8 are average, ND9 is significantly worse than average, and ND4 and ND6 are significantly better. Therefore, as the masking ability of the PICN material depends on the substrate material, the third hypothesis was rejected. The effect of substrate or background color is also discussed in previous studies, albeit with a smaller number of substrate samples.[26,28] Masking ability of hybrid ceramics was evaluated on substrates made of amalgam, titanium, and composite filling material—simulating enamel and dentin—by Afouzan et al. In contrast to the present study, it was found that although the substrate material affected the color appearance of the samples, these values were not statistically significant.[26] Porojan et al. used three substrates made of composite to examine hybrid ceramics. Based on the results obtained, it was found that the color of the substrate significantly affects the masking ability of the ceramic.[28]

4. The effect of translucency on masking ability is manifested both in the different multipliers of the multiplicative effect and in the different group ΔE_{00} averages. With *T* ceramics in a thickness of 2.0 mm, a result, significantly below the acceptability threshold, can be achieved with any substrate material except ND9, while in the case of HT ceramics, this cannot be stated with such certainty even with a thickness of 2.5 mm. Based on the aforementioned results, as translucency definitely has an effect on the masking ability of the ceramic, the fourth hypothesis was also rejected. To the best of our knowledge, previous studies on the masking ability of hybrid ceramics examined the materials only in one translucency, with the exception of one publication in 2021.[30] Pop-Ciutrila et al. examined PICN materials in two translucencies (T and HT), similar to the present research. They found that the masking ability of hybrid ceramics of the same shade and thickness, but of different translucency, is significantly different from one another, therefore the results correlate with the present study.[30]

Overall, the results of this study are in accordance with previous research results discussing PICN materials. Although the literature abounds with results regarding the factors affecting the masking ability of the most commonly used dental ceramics, there is a lack of information about the optical properties of hybrid ceramics, even though they are used in increasing numbers nowadays and, according to professional opinions, have a great future. The purpose of this study is to show that problems that arise during every day esthetic dental care (e.g., discolored abutments, issues of material and translucency choice) can become overcomeable challenges with the right knowledge.

It is important to emphasize that the results come from an in vitro research which need to be taken with caution outside of the experimental environment. Although the method used is adequate for examining factors influencing the optical properties of PICN materials, the perfect simulation of in vivo conditions (convex and wet surfaces, natural tooth tissues, etc.) is yet unsolved.

5 | CONCLUSIONS

Within the limitations of this current study, the following conclusions were established:

1. Reflection of the examined polymer-infiltrated ceramic-network material is characterized by both diffuse and specular reflection.
2. Masking ability of the examined polymer-infiltrated ceramic-network material increases exponentially with the increase of layer thickness, according to a constant multiplier, as a characteristic of the material.
3. By examining nine substrate materials, it was found that in the case of translucent polymer-infiltrated ceramic-network material, three, in the case of high translucent material, five substrates significantly influenced the masking ability of the polymer-infiltrated ceramic-network material.
4. Masking ability of high translucent and translucent polymer-infiltrated ceramic-network materials is significantly different.

CONFLICT OF INTEREST STATEMENT

The authors declare that they do not have any financial interest in the companies whose materials are included in this article.

DATA AVAILABILITY STATEMENT

Research data are not shared.

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REFERENCES

1. Sulaiman TA. Materials in digital dentistry—a review. *J Esthet Restor Dent*. 2020;32(2):171-181.
2. Fasbinder DJ. Digital dentistry: innovation for restorative treatment. *Compend Contin Educ Dent*. 2010;31(4):2-11.
3. Abduo J, Lyons K, Bennamoun M. Trends in computer-aided manufacturing in prosthodontics: a review of the available streams. *Int J Dent*. 2014;2014:783948.
4. Steinbrenner H. Multichromatic and highly translucent hybrid ceramic Vita Enamic. *Int J Comput Dent*. 2018;21(3):239-250.
5. Kihara H, Hatakeyama W, Komine F, et al. Accuracy and practicality of intraoral scanner in dentistry: a literature review. *J Prosthodont Res*. 2020;64(2):109-113.
6. Blatz MB, Conejo J. The current state of chairside digital dentistry and materials. *Dent Clin N Am*. 2019;63(2):175-197.
7. Awada A, Nathanson D. Mechanical properties of resin-ceramic CAD/CAM restorative materials. *J Prosthet Dent*. 2015;114(4):587-593.
8. Coldea A, Swain MV, Thiel N. Mechanical properties of polymer-infiltrated-ceramic-network materials. *Dent Mater*. 2013;29(4):419-426.
9. Laborie M, Naveau A, Menard A. CAD-CAM resin-ceramic material wear: a systematic review. *J Prosthet Dent*. 2022. doi:10.1016/j.prosdent.2022.01.027
10. He LH, Swain M. A novel polymer infiltrated ceramic dental material. *Dent Mater*. 2011;27(6):527-534.
11. Facenda JC, Borba M, Corazza PH. A literature review on the new polymer-infiltrated ceramic-network material (PICN). *J Esthet Restor Dent*. 2018;30(4):281-286.
12. Dirxen C, Blunck U, Preissner S. Clinical performance of a new biomimetic double network material. *Open Dent J*. 2013;7:118-122.
13. Xu Z, Yu P, Arola DD, Min J, Gao S. A comparative study on the wear behavior of a polymer infiltrated ceramic network (PICN) material and tooth enamel. *Dent Mater*. 2017;33(12):1351-1361.
14. Palacios T, Tarancón S, Pastor JY. On the mechanical properties of hybrid dental materials for CAD/CAM restorations. *Polymers*. 2022;14(16):3252.
15. Tokunaga J, Ikeda H, Nagamatsu Y, et al. Wear of polymer-infiltrated ceramic network materials against enamel. *Materials*. 2022;15(7):2435.
16. Della Bona A, Corazza PH, Zhang Y. Characterization of a polymer-infiltrated ceramic-network material. *Dent Mater*. 2014;30(5):564-569.

17. Joiner A, Luo W. Tooth colour and whiteness: a review. *J Dent*. 2017; 67:S3-S10.
18. Chaiyabutr Y, Kois JC, Lebeau D, Nunokawa G. Effect of abutment tooth color, cement color, and ceramic thickness on the resulting optical color of a CAD/CAM glass-ceramic lithium disilicate-reinforced crown. *J Prosthet Dent*. 2011;105(2):83-90.
19. Miura S, Tsukada S, Fujita T, et al. Effects of abutment tooth and luting agent colors on final color of high-translucent zirconia crowns. *J Prosthodont Res*. 2021;66:243-249.
20. Czigola A, Abram E, Kovacs ZI, Marton K, Hermann P, Borbely J. Effects of substrate, ceramic thickness, translucency, and cement shade on the color of CAD/CAM lithium-disilicate crowns. *J Esthet Restor Dent*. 2019;31(5):457-464.
21. Abram E, Gajdatsy G, Hermann P, Ujhelyi F, Borbely J, Shen JZ. The colour of monolithic zirconia restorations determined by spectrophotometric examination. *Adv Appl Ceram*. 2019;118(1–2):3-8.
22. Abram E, Gajtdatsy G, Feher D, et al. Spectrophotometric examination of the optical effects of monolithic multilayered zirconia with different substrates. *Adv Appl Ceram*. 2020;119(5–6):261-266.
23. Tabatabaian F, Dalirani S, Namdari M. Effect of thickness of zirconia ceramic on its masking ability: an In vitro study. *J Prosthodont*. 2019; 28(6):666-671.
24. Juntavee N, Juntavee A, Phetpanompond S. Masking ability of different ceramics upon various underlying structures. *J Esthet Restor Dent*. 2022;34(2):430-439.
25. Chongkavinit P, Anunmana C. Optical effect of resin cement, abutment material, and ceramic thickness on the final shade of CAD-CAM ceramic restorations. *J Prosthet Dent*. 2021;125(3):517.e511-517.e518.
26. Alfouzan AF, Alnafaiy SM, Alsaleh LS, et al. Effects of background color and thickness on the optical properties of CAD-CAM resin-matrix ceramics. *J Prosthet Dent*. 2022;128(3):497.e491-497.e499.
27. Ruiz-López J, Espinar C, Lucena C, de la Cruz Cardona J, Pulgar R, Pérez MM. Effect of thickness on color and translucency of a multi-color polymer-infiltrated ceramic-network material. *J Esthet Restor Dent*. 2022;35:381-389.
28. Porojan L, Vasiliu RD, Porojan SD. Masking abilities of dental cad/cam resin composite materials related to substrate and luting material. *Polymers*. 2022;14(3):364.
29. Pop-Ciutrila IS, Ghinea R, Colosi HA, et al. Color compatibility between dental structures and three different types of ceramic systems. *BMC Oral Health*. 2021;21(1):75.
30. Pop-Ciutrila IS, Ghinea R, Dudea D, Ruiz-López J, Pérez MM, Colosi H. The effects of thickness and shade on translucency parameters of contemporary, esthetic dental ceramics. *J Esthet Restor Dent*. 2021;33(5):795-806.
31. Pulgar R, Lucena C, Espinar C, et al. Optical and colorimetric evaluation of a multi-color polymer-infiltrated ceramic-network material. *Dent Mater*. 2019;35(7):e131-e139.
32. Egilmez F, Ergun G, Cekic-Nagas I, Vallittu PK, Lassila LVJ. Comparative color and surface parameters of current esthetic restorative CAD/CAM materials. *J Adv Prosthodont*. 2018;10(1):32-42.
33. Luo M, Cui G, Rigg B. The development of the CIE 2000 colour-difference formula: CIEDE2000. *Color Res Appl*. 2001;26: 340-350.
34. CIE. *CIE Technical Report: Colorimetry*. CIE Central Bureau; 2004.
35. Ghinea R, Pérez MM, Herrera LJ, Rivas MJ, Yebra A, Paravina RD. Color difference thresholds in dental ceramics. *J Dent*. 2010;38: 57-64.
36. Paravina RD, Ghinea R, Herrera LJ, et al. Color difference thresholds in dentistry. *J Esthet Restor Dent*. 2015;27:1-9.
37. Paravina RD, Pérez MM, Ghinea R. Acceptability and perceptibility thresholds in dentistry: a comprehensive review of clinical and research applications. *J Esthet Restor Dent*. 2019;31(2):103-112.
38. Alharbi N, Teerakanok S, Satterthwaite JD, Giordano R, Silikas N. Quantitative nano-mechanical mapping AFM-based method for elastic modulus and surface roughness measurements of model polymer infiltrated ceramics. *Dent Mater*. 2022;38(6):935-945.

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