Original Article

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Influence of Different Thicknesses of Advanced Lithium Disilicate Ceramic on the Color Changes over a Dark Substrate (An in-vitro study)

Areej Z. Saleh [1]*; Omaima El-Mahallawi[2]; KarimAwadallah[3]

Abstract:

Objective: This study aimed to evaluate the effect of varying thicknesses of two lithium disilicate ceramics on the final color outcome when placed over a dark background.
Materials and Methods:30 rectangular-shaped12x14mm samples of advanced lithium disilicate (Cerec Tessera)and lithium disilicate ceramic (e.max).Samples were prepared using a CAD/CAM milling machine and categorized into two groups;(LiSiE&LiSiT) and into three subgroups according to different thicknesses0.5 mm,1mm,and1.5mm with(n=5/subgroup).A Complete image spectrophotometer(UltraScan PRO,HunterLab)was used to measure the color difference(ΔE)when the specimens were placed over a dark composite substrate(shadeA3.5)compared to a standard shadeA2.Intergroup differences were analyzed using independent t-tests, while intra group comparisons were conducted with repeated measures ANOVA and Bonferroni-adjusted pair wise tests. Variable interactions were evaluated by two-way ANOVA, and overall group comparisons, irrespective of variables, were performed using one-way ANOVA followed by Tukey's post hoc test.
Results: LiSiT consistently exhibited significantly lower ΔE values than LiSi Eat all thicknesses ($P< 0.05$),indicating superior masking ability. Within each material, increasing thickness resulted in a significantly reduced color difference ($P< 0.001$).Two-way ANOVA confirmed significant effects of material and thickness on color difference, but no significant interaction effect. Overall, LiSiT at1.5mm showed the least perceptible color change, supporting its use in esthetically demanding restorations.
Conclusion: Within the limitations of this study, LiSiT demonstrated better color outcome than LiSi E, particularly at greater thicknesses. The material and thickness both played a role in determining the color difference, with thicker materials showing more consistency in color. Overall, material choice and thickness are key factors to consider when aiming for optimal aesthetic outcomes in dental restorations.
Keywords: Lithium disilicate, ceramic thickness, Computer-aided design/computer-aided manufacturing, color changes, dark substrate, dental ceramics, esthetics, ΔE values, masking ability, spectrophotometry.

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[1]*MSc. Student, Fixed Department, Faculty of Dentistry, Cairo University, Cairo, Egypt
Email: areej.zakareya@dentistry.cu.edu.eg
[2]Professor, Fixed Department, Faculty of Dentistry, Cairo University, Cairo, Egypt
[3]Assistant Professor, Fixed Department, Faculty of Dentistry, Cairo University, Cairo, Egypt

Introduction:

The demand for dental restorations that closely replicate the natural appearance of teeth has grown significantly over the last few decades. This is particularly critical in anterior restorations, where even minor discrepancies in color or translucency can negatively impact the overall aesthetics of a smile. With increasing awareness of dental aesthetics and its impact on self-confidence, patients now seek restorations that not only restore function but also seamlessly blend with natural dentition.[1]

Dental ceramics have transformed modern restorative dentistry, offering aesthetically pleasing and durable solutions that closely resemble natural teeth. These materials have become essential in addressing the increasing demand for restorations that integrate seamlessly with the surrounding dentition. [2] Traditional restorative materials, such as metal alloys, often lacked the translucency and color variation necessary for aesthetic success. The introduction of advanced ceramics, particularly lithium disilicate, has revolutionized dental restorations by improving both functional and aesthetic outcomes. [3]

Advancements in dental ceramics significantly contributed to meet these aesthetic demands. Among the materials available, lithium disilicate ceramics have become widely favored because of their superior optical properties, mechanical strength, and biocompatibility. These ceramics closely mimic the translucency of natural enamel, allowing clinicians to achieve highly aesthetic results.[4]However, the interaction between the ceramic material and the underlying tooth substrate significantly affects the final appearance when placed over a dark substrate, the thickness of the lithium disilicate ceramic becomes a determining factor in how much of the underlying shade is masked. Thinner restorations may allow the dark substrate to show through, compromising the aesthetic outcome, whereas thicker restorations offer improved masking but may impact translucency and light transmission.[5]

Lithium disilicate glass ceramics are widely regarded for their strength and ability to replicate enamel-like translucency. Their optical properties enable light transmission, reflection, and absorption in a manner similar to natural teeth, making them an ideal choice for crowns, veneers, inlays, and other highly visible restorations.[6]However, when restorations are placed over dark substrates, challenges arise in achieving the desired aesthetic outcome. The thickness of the lithium disilicate ceramic plays a crucial role in color matching, influencing the degree of translucency and the extent to which the underlying color is masked. [7]

Studies have shown that thicker ceramic layers improve masking ability by reducing the influence of the dark substrate. However, excessively thick restorations may compromise the natural translucency that contributes to lifelike aesthetics.[8] The interaction between ceramic thickness and substrate color is complex, requiring careful material selection and clinical judgment to achieve optimal results.[9]

Advanced lithium disilicate ceramics, such as CEREC Tessera (LiSi T), offer superior masking ability at thinner sections due to their enhanced optical properties. Their composition, including virgilite crystals, contributes to improved translucency and color stability, allowing effective camouflage of dark substrates without excessive thickness. This balance between opacity and translucency enables esthetically pleasing restorations while preserving natural tooth structure.[10]In addition to thickness, other factors influence the final appearance of ceramic restorations, including the properties of luting cements, the substrate material, and the optical characteristics of the ceramics used.[11]

Different measurement techniques have been developed to assess color differences in dental restorations. Among visual and digital shade matching devices, Complete image spectrophotometers offer objective and quantifiable analysis, improving precision in color matching. The CIE L*a*b* color system is commonly used to evaluate chromatic differences, with ΔE values providing a numerical measure of perceptible color changes.[12]

Despite considerable progress in ceramic materials and color evaluation techniques, further research is necessary to more comprehensively evaluate the effectiveness of color masking of advanced lithium disilicate ceramics when applied over dark substrates. Understanding how varying thicknesses affect optical properties will help clinicians make informed decisions when selecting restorative materials.

This study aimed to evaluate the effect of varying thicknesses of two lithium disilicate ceramics on the final color outcome when placed over a dark background.

The null hypothesis of the current study states that different ceramic thicknesses and compositions would not have an impact on their shade masking ability over dark substrate

Material and Method:

Sample size calculation:

As demonstrated in a previous study by Al-Ayad et al. (2021)[13], the ΔE values within the lithium disilicate group at a thickness of 1.5 mm were normally distributed with a standard deviation of 0.32. Assuming a true mean difference of 0.75 between advanced lithium disilicate and conventional lithium disilicate, a sample size of 4 specimens per subgroup would be required to detect this difference with a statistical power of 0.8. The Type I error probability associated with this test of this null hypothesis is 0.05. To account for the possibility of a non-parametric distribution, the sample size was increased by 25%, resulting in 5 specimens per subgroup and a total sample size of 30. The sample size calculation was performed using PS Power and Sample Size Software, version 3.1.6 for Windows, based on an independent t-test.

Materials used

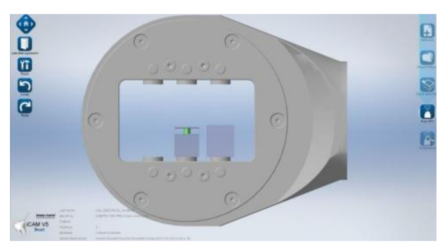
The study utilized lithium disilicate ceramics, including HT (A2) IPS e.max CAD blocks (Ivoclar Vivadent, Germany) and Dentsply CEREC Tessera (Dentsply Sirona, USA)

Additionally, different resin composites (Filtek™ Z250XT, 3M™ ESPE™*)* were used to simulate dark and normal tooth substrates, including, Resin composite A3.5 (to represent dark tooth substrate) and Resin composite A2 (to simulate normal tooth shade) **Table (1).**

Sample Preparation

30rectangular-shaped plates specimens with dimensions of (12mm length and 14mmwidth)[14] of LiSi E and LiSi T (0.5, 1,1,5mm)[15] were designed using a CAD designing software(Blender Foundation, Amsterdam, Netherlands)and was exported as a Standard Tessellation Language (STL) file and imported into DENTALCAM software (CORiTEC350iPRO,imes-icore GmbH, Hessen, Germany).

Through the CAM software nesting placement of the samples was performed to ensure optimal material utilization (Figure 1), supporting structures were added to the outer surface of each disc to facilitate handling during milling. The milling process was carried out using a five-axis CORiTEC350iPRO under manufacturer-recommended parameters. [16,17](Figure 2).



(Figure 1): Nesting layout of the specimens in the CAM software, showing optimized placement and support structures for milling.

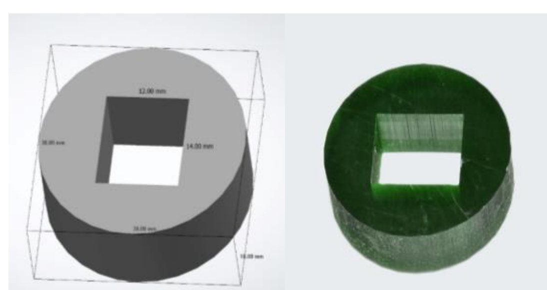
(Figure 2): (A)Milled Lisi T specimens attached to support structure.(B)Milled Lisi Especimens before support removal.

After milling, all ceramic discs were handled by a single operator to maintain standardization. The supporting structures were carefully removed using high-precision separating (cutting) discs, and the samples were cleaned using ultrasonic cleaning in deionized water to eliminate residual milling debris. For the surface finishing and polishing, all specimens were finished and polished based on the manufacturer's protocol, the thickness of each specimen was then confirmed using a digital caliper to ensure accuracy[16](±0.01 mm accuracy), confirming that all specimens adhered to their designated thickness categories (0.5 mm, 1.0 mm, 1.5 mm).All ceramic specimens, including LiSi E andLiSi T, underwent a combined crystallization and glazing cycle using the Program at EP 3010 furnace (Ivoclar Vivadent) to ensure uniform thermal treatment. Prior to firing, a single layer of manufacturer-recommended glaze was applied to each specimen (Universal overglaze, Dentsply Sirona) was applied to all LiSi T samples and (IPS e.max Ceram Glaze Paste) for LiSi E samples. The crystallization–glazing program for LiSi E began at a starting temperature of 403°C, with a heating rate of 90°C/min, reaching a final temperature of 850°C, which was maintained for 70minutes, while The crystallization–glazing program for LiSi T began at a starting temperature of 403°C, with a heating rate of 55°C/min, reaching a final temperature of 760°C, which was maintained for 2 minutes following manufacturers' instruction.

Fabrication of Background

Mold Design:

A mold containing centrally placed rectangular opening (12 × 14 mm) with a thickness of 10 mm, was created in STL format using Blender software (Blender Foundation, Amsterdam, Netherlands). A schematic diagram of the mold is shown in (Figure 3). The STL file was subsequently exported into Chitubox software (Shenzhen, China).[18]



(Figure 3): (A) Schematic diagram of the mold (B) The final printed mold.

Substrate Construction

A3.5 & A2 resin composites simulating dark & light (control group) substrates respectively were used[19,20] ,the borders of the mold were coated with a thin layer of glycerin separating medium using a camel hair brush, and the mold was then placed onto a clean, dry glass slab.

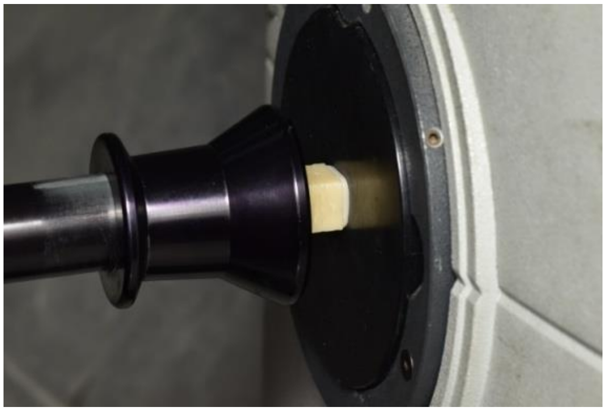
Resin Application and Layering

The resin composite was incrementally layered in 1 mm increments onto a glass substrate using a gold-coated applicator. To ensure uniform surface integrity, each increment was covered with a mylar strip prior to polymerization. Light curing was performed for 40 seconds per layer utilizing a light-emitting diode (LED) unit operating at an intensity of 1400 mW/cm² within a wavelength range of 420–480 nm, with a positioning tip maintaining standardized distance. This sequential layering and curing protocol continued until the desired anatomical contour was achieved. Following polymerization of the final increment, the mold and mylar strip were carefully detached, and an additional 40-second curing cycle was conducted to optimize polymerization completeness. Finally, all specimens were finished and polished using (Kenda CGI, Moscow, Russia). [21]

Color Measurement

A spectrophotometer (Hunter Associates Laboratory, Inc., Reston, VA, USA)[22] was used (Figure 4) to measure color differences (ΔE values) between samples of different thicknesses. The device was configured with a white background, a D65 standard illuminant, a 10° observer angle, 100% UV energy, and a small aperture size. To maintain measurement consistency, the same background, operator, measurement location, and lighting conditions were used for all specimens (Figure5). The spectrophotometer was calibrated before each set of measurements.

(Figure 4): Spectrophotometer used for measuring ΔE.



(Figure 5): Specimen under test in the spectrophotometer.

Masking ability was assessed by calculating the color difference (ΔE) between the A2 control group and each sample layered over the A3.5 dark substrate. ΔE values were determined using the Commission International de l'Eclairage (CIE) Lab formula[21], which defines color in terms of three parameters: L* (lightness), a* (red–green axis), and b* (yellow–blue axis). Variations in ΔL*, Δa*, and Δb* were also analyzed as part of the evaluation.

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

The CIE Lab color system was used to determine lightness, red-green variation, and yellow-blue variation.

Statistical analysis

Data analysis was carried out using MedCalc software, version 22 for Windows (MedCalc Software Ltd, Ostend, Belgium). The distribution of continuous variables was assessed using the Kolmogorov–Smirnov and Shapiro–Wilk tests to confirm normality. As the data were normally distributed, they were reported as means with standard deviations. Comparisons between different groups were performed using independent t-tests, while repeated measures ANOVA with Bonferroni-adjusted pair wise comparisons was used for within-group analyses. Two-way ANOVA was employed to evaluate interactions between variables, and one-way ANOVA followed by Tukey's post hoc test was used for overall group comparisons, independent of specific variables. The statistical power was set at 80%, with a significance level of $P \leq 0.05$ (adjusted when applicable using Bonferroni correction) and a 95% confidence interval. All analyses were two-tailed.

Results:

Color difference:

1- Effect of material on color difference within each thickness (Table 2):

0.5 mm:

Intergroup comparison has shown a statistically significant difference between LiSi T and LiSi E($P = 0.0003$). LiSi Thas shown less color difference when compared to LiSi E with a mean difference of 0.78±0.20 showing a very large Cohen's d effect size of 3.9.

1 mm:

Intergroup comparison has shown a statistically significant difference between LiSi T and LiSi E(P = 0.0006). LiSi T has shown less color difference when compared to LisiE with a mean difference of 0.63±0.18 showing a very large Cohen's d effect size of 3.5.

1.5 mm:

Intergroup comparison has shown a statistically significant difference between Lisi T and Lisi E (P = 0.0329). Lisi T has shown less color difference when compared to Lisi Ewith a mean difference of 0.50±0.31 showing a very large Cohen's d effect size of 1.61.

2- Effect of thickness on color difference within each material (Table 3):

Lisi T:

Intragroup comparison has shown a statistically significant difference between different thicknesses (P < 0.001). The highest color difference was within 0.5 mm thickness, followed by 1 mm thickness, then the least color difference within 1.5 mm thickness.

LiSi E:

Intragroup comparison has shown a statistically significant difference between different thicknesses (P < 0.001). The highest color difference was within 0.5 mm thickness, followed by 1 mm thickness, then the least color difference within 1.5 mm thickness.

3- Effect of interaction of material and thickness on color difference:

Two-way ANOVA revealed statistically significant effect of material and thickness on color difference (P < 0.001), while interaction of material and thickness did not show statistically significant effect on color difference (P = 0.455).

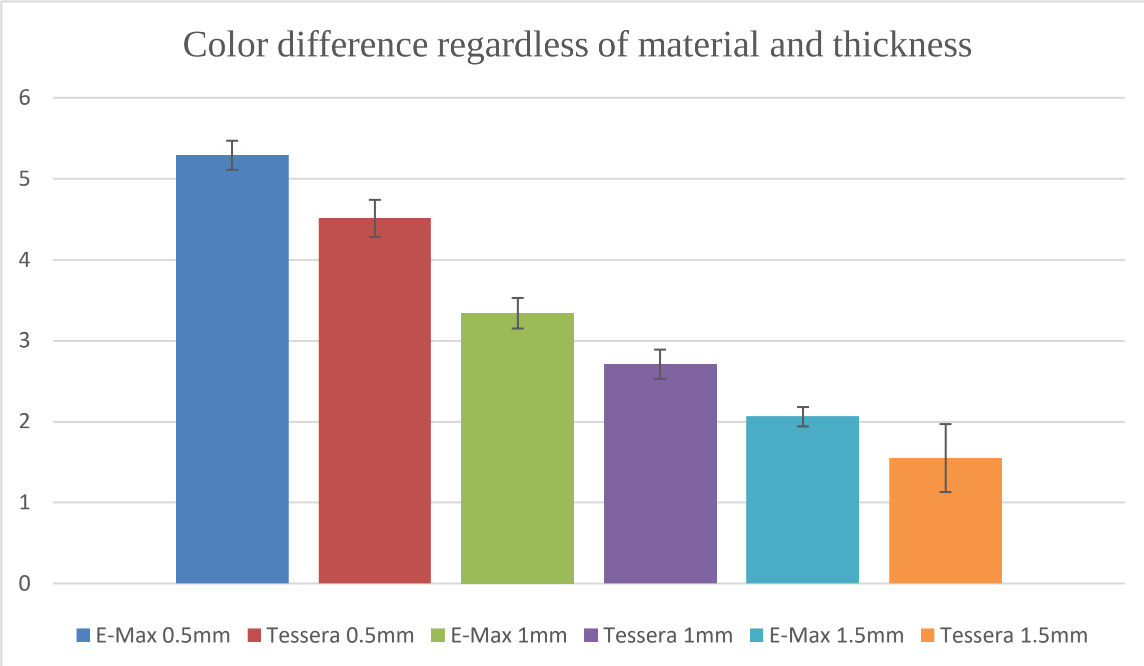
Comparison across all groups, regardless of material and thickness, revealed a statistically significant difference (P < 0.001). The highest color difference was observed in LiSi E at 0.5 mm thickness, followed by LiSi T at 0.5 mm, then LiSi Eat 1 mm, LiSi T at 1 mm, and LiSi Eat 1.5 mm thickness. The lowest color difference was found in LiSi T at 1.5 mm thickness. All groups differed significantly from one another. (Figure 6)

(Table 2): Mean and SD of color difference (ΔE) of each material with different thickness

Material Thickness	LiSi T		LiSi E		Difference		P value
	Mean	SD	Mean	SD	Mean	SD	
0.5 mm	4.51	0.23	5.29	0.18	0.78	0.20	P = 0.0003*
1 mm	2.70	0.17	3.33	0.18	0.63	0.18	P = 0.0006*
1.5 mm	1.55	0.42	2.05	0.12	0.50	0.31	P = 0.0329*

(Table 3): Mean and SD of color difference (ΔE) of Lisi T and Lisi using different

Material Thickness	LiSi T		LiSi E	
	Mean	SD	Mean	SD
0.5 mm	4.51[a]	0.23	5.29[a]	0.18
1 mm	2.70[b]	0.17	3.33[b]	0.18
1.5 mm	1.55[c]	0.42	2.05[c]	0.12
P value	P <0.001*		P <0.001*	



(Figure 6): Bar chart showing mean color difference regardless of material and thickness.

Discussion :

This study focuses on achieving optimal aesthetics in restorative dentistry, particularly when dealing with dark underlying substrates. Lithium disilicate ceramics are widely used due to their combination of translucency and strength; however, their ability to mask dark backgrounds is largely influenced by the material's thickness. Advanced lithium disilicate materials like CEREC Tessera have emerged, offering enhanced optical characteristics and mechanical properties, although limited studies have examined their masking effectiveness.[13]

Achieving natural-looking restorations requires an understanding of the interaction between hue, value, and chroma, and how these elements respond to variations in substrate color. Highly translucent ceramic materials allow light transmission, which increases the visibility of the underlying structure and subsequently impacts the final color of the restoration. Therefore, selecting materials with an appropriate balance of translucency and opacity is critical for optimal aesthetic performance.[23]

The study was designed to mimic clinical scenarios by evaluating ceramic specimens with varying thicknesses of 0.5 mm, 1.0 mm, and 1.5 mm. These values reflect conservative preparation techniques and standard restorative protocols, where minimal invasiveness must be balanced with esthetic demands [15]**.** The ceramic samples were digitally designed and precisely milled using a 5-axis milling machine to ensure consistent thickness and surface characteristicswhich are essential for accurate and reproducible color assessments.[16]

According to the used material type, IPS e.max CAD (Ivoclar Vivadent, Liechtenstein) and CEREC Tessera (Dentsply Sirona, USA) were fired for crystallization and glazing in a compatible ceramic furnace (Programat EP3010, Ivoclar Vivadent, Germany) following their manufacturer's instructions.[24]

In the selection of substrates, A3.5 was chosen as the test shade due to its representation of a medium-dark shade commonly seen in clinical cases involving discolored dentin or previous restorations. This makes A3.5 a realistic and meaningful substrate for assessing masking performance. A2 was selected as the reference shade, reflecting a common tooth color encountered in clinical practice. This contrast provides a practical framework for evaluating color difference and masking effectiveness.[19]

To maintain consistent substrate dimensions and experimental conditions, 3D-printed molds were utilized[18]**.** Furthermore, to isolate the influence of ceramic type and thickness on color masking, no cement was used in the study as **Zhu et al., 2024.**[15]reported, the shade and translucency of resin cement can significantly affect the final optical outcome of ceramic restorations, potentially introducing confounding variables. Excluding cement ensures that anychanges in color observed can be directly linked to the specific ceramic materials under study.

Color differences (ΔE) were measured using a spectrophotometer based on the CIELAB color space under standardized conditions. Before measurement, the specimens were cleaned and polished to remove any surfaceartifacts.[25]

The results demonstrated that both material and thickness had statistically significant effects on ΔE values. LiSi T consistently yielded lower ΔE values compared to LiSi E across all thickness groups, indicating a superior masking capacity. These findings correspond with those reported by **Sancaktar et al. (2023) and Pala et al. (2024)**[7,8], who highlighted the impact of ceramic microstructure and composition on light scattering and optical properties.

LiSi T superior masking ability is primarily due to its unique microstructural composition asstudies have shown that virgilite crystals enhance optical opacity by increasing internal light scattering and reducing light transmission. Research on zirconia-reinforced lithium silicate ceramics confirms that hexagonal-like virgilite crystals aggregate due to molecular movement, affecting translucency.[26,27]

The incorporation of zirconia in lithium silicate ceramics improves mechanical strength and optical properties. According tomanufacture, zirconia particles act like a reinforcing barwhich increasesits tensile strength and durability,material density and preventing crack propagation. [28]

The glassy matrix in LiSi T is engineered to balance translucency and opacity. Studies on historical glass mosaic tesserae have demonstrated how glass matrices and opacifiers influence optical properties. [29]

Differences in translucency between the materials are likely due to variations in their crystal structures. The advanced lithium disilicate incorporates virgilite in its matrix, which may reduce its translucency compared to standard lithium disilicate. Additionally, the lithium disilicate crystals in the conventional material are larger, measuring over 1 μm, whereas those in the advanced lithium disilicate are smaller, around 0.5 μm, with virgilite crystals even finer, ranging from 0.2 to 0.3 μm. [30]

Consistent with prior research, an increase in ceramic thickness was associated with a significant reduction in ΔE values for both materials. Thicker ceramics attenuate light transmission more effectively, reducing the visual influence of the substrate and improving color match, [5, 9] clinicallythis is essential in restoring teeth with intrinsic discoloration or dark core build-ups.

Based on the results of this study that different ceramic thicknesses and compositions would not have an impact on their shade masking ability over dark substrate between tested groups the null hypothesis was rejected.

Limitations :

The study was performed under controlled laboratory conditions and did not simulate the complex, dynamic environment of the oral cavity. The evaluation was conducted without using resin cement, which, while isolating the ceramic's masking ability, limits the clinical application of the results since cement can significantly affect the final optical outcome.

Moreover, using standardized, rectangular plate specimens may not adequately reflect the varied geometries and thicknesses encountered in clinical restorations. Finally, only two types of lithium disilicate ceramics and a limited range of substrate shades were evaluated, which may reduce the generalizability of the findings to everyday dental practice.

Conclusion :

This study demonstrated that both the type of ceramic material and its thickness significantly influence the color masking ability over dark substrates. Advanced lithium disilicate consistently exhibited superior masking performance compared to lithium disilicate across all tested thicknesses, with the lowest ΔE values observed at 1.5 mm. Increasing the thickness of both materials resulted in a notable improvement in color matching, reinforcing the importance of material selection and proper thickness for esthetic success. These findings highlight the clinical advantage of advanced lithium disilicate ceramics in cases requiring effective masking, especially when minimal invasiveness must be balanced with optimal esthetic outcomes.

Recommendations

1. Further investigations, particularly in vivo or clinically simulated studies with greater clinical resemblance, are recommended to better replicate the oral environment, including variables such as saliva, lighting, and temperature fluctuations.
2. Incorporating resin cements in future research is essential, as their shade and translucency can significantly influence the final color outcome over dark substrates.
3. Using anatomically shaped restorations instead of flat specimens is recommended to better reflect real clinical situations and variable thicknesses.
4. Since this study used high-translucency ceramics, which are more affected by dark substrates, it is recommended to use low or medium translucency (LT or MT) ceramics for better masking in clinical practice.

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