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Impact of restoration thickness and tooth shade background on the translucency of zirconia laminate veneers: An in vitro comparative study

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ABSTRACT

Purpose: Our in vitro comparative study aimed to investigate the impact of thickness and tooth shade background on the translucency of highly translucent zirconia veneers.
Materials and Methods: A total of 75 5Y-TZP zirconia veneers of shade A1 were fabricated with thicknesses of 0.50 mm (n = 25), 0.75 mm (n = 25), and 1.0 mm (n = 25). The translucencies were measured on composite resin teeth with shades A1, A2, A3, A3.5, and A4 using a digital color imaging spectrophotometer. Data were analyzed using ANOVA and post hoc Tukey's test ($p < 0.05$).
Results: The translucency values were optimal for the veneers placed over the substrate teeth with shades A1 and A2, regardless of the veneer thickness. Additionally, veneers with a thickness of 0.50 mm exhibited significantly higher translucency than those with thicknesses of 0.75 mm and 1.0 mm.
Conclusions: Our study demonstrated that the translucency of the highly translucent zirconia veneers was influenced by both veneer thickness and tooth shade background. The optimal veneer thickness for achieving the highest translucency was 0.50 for the veneers with A1 and A2 shades placed over the substrate teeth.
Clinical Relevance: The optimal thickness for achieving the highest translucency of the highly translucent zirconia laminate veneers was 0.50 mm for the veneers with A1 and A2 shades placed over the substrate teeth. Clinicians and dental technicians could consider this when selecting materials for aesthetic restorations.

1. Introduction

Patients increasingly seek aesthetic dental treatments, and laminate veneer (LV) restorations are a popular option (Afrashtehfar and Assery, 2014; Jurado et al., 2020). Ceramic LVs are often used to address issues, such as incisal wear, facial defects, fractures, tooth discoloration, and interdental spaces in a conservative manner, since they only require the reduction of 25–50 % of tooth structure compared to traditional full coverage restorations (Edelhoff and Sorensen, 2002; Villalobos-Tinoco et al., 2020). Conservative preparations for LV restorations have been well documented in the literature and enable the fabrication of thin, bondable restorations on enamel tooth structure (Afrashtehfar, 2021; Villalobos-Tinoco et al., 2022).

Clinicians have a variety of ceramics to choose from when fabricating labial LVs, including lithium disilicate, feldspathic porcelain, leucite, zirconia, and combinations of these materials (Afrashtehfar et al., 2015; Jurado et al., 2021; Jurado et al., 2022). Zirconia, due to its high mechanical properties and good esthetic results for crowns, is currently being used for LV restorations (Alikhasi et al., 2022; Lawson et al., 2019). The newer generation of zirconia with higher yttria content

Abbreviations: **LV**, Laminate veneer; **Y-PSZ**, Yttria-stabilized tetragonal zirconia polycrystals; **ΔE**, Color difference; **ΔL**, Lightness difference; **ANOVA**, Analysis of variance; **IoS**, Intraoral dcanner; **LCD**, Liquid crystal display.

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has improved optical properties and maintains its high fracture resistance, which is superior to other ceramics on the market (Bankoğlu et al. 2018). It has been shown that increasing the yttria content to 5 mol% can significantly increase its translucency, causing it to be comparable or even superior to lithium disilicate glass ceramic (Jurado et al., 2023).

Translucency is the amount of light diffusing from the substrate to the surface (Zhang et al., 2021). Translucency is an essential factor in ceramic selection because it is directly related to the natural appearance of the restoration. Techniques to increase translucency in zirconia include modifying the microstructure to prevent light interference, increasing the cubic phase, and reducing porosity after sintering (Papageorgiou-Kyrana et al., 2020). The grain size of third-generation zirconia (5Y-PSZ) was reported to be within the range of 1.17 ± 0.19 µm, while second-generation zirconia (3Y-PSZ) had a size range of 0.57 ± 0.14 µm (Mao et al., 2018).

Translucency can be measured with various equations and instruments, such as spectrophotometers; these are digital devices used to measure the optical properties of teeth and ceramics in dentistry, usually over black and white backgrounds (Ishikawa-Nagai et al., 2010). Spectrophotometers are reliable and accurate methods for overall color matching in dental medicine (Igiel et al., 2017; Paul et al., 2005). They can be used to quantify the energy reflected on the tooth or restoration over short intervals along the visible spectrum (Kielbassa et al., 2009; Lagouvardos et al., 2009). The observations performed by the human eye were compared to those of spectrophotometers, and the latter showed 33 % higher accuracy and higher objective matching in 93.3 % of clinical scenarios (Paul et al., 2005). However, no data exist on the translucency of zirconia LVs with different tooth shade backgrounds with the use of a digital color spectrophotometer. Therefore, our study assessed the translucency of zirconia LVs with various thicknesses over different background tooth shades. Our first null hypothesis was that the thickness of the zirconia LV did not influence the translucency values. The second null hypothesis was that the different tooth background shades did not impact the translucency values of the zirconia LVs.

2. Materials and methods

2.1. Experimental setup and sample preparation

Three typodont teeth (1560 Dentoform; Columbia Dentoform, Lancaster, PA, USA) maxillary left central incisors were prepared for labial butt joint LVs with 1.00 mm, 0.75 mm, and 0.50 mm and an incisal reduction of 1.0 mm. The teeth were scanned with a chair-side intraoral scanner (IoS; Emerald S IoS, Planmeca) and built-in software (PlanCAD Easy, Planmeca). Seventy-five translucent (5Y-TZP) zirconia LV (Katana UTML, Kuraray Noritake) restorations were milled (PrograMill PM7, Ivoclar Vivadent), glazed (Cerabien ZR FC, Kuraray Noritake), sintered in a furnace (Programat S2, Ivoclar Vivadent) by an experienced dental technician and polished (Zirconia Polisher, Kerr Corporation) by a single prosthodontist following the manufacturer's instructions.

The three prepared teeth were duplicated with putty indexes (Splash, Dent-Mat Holdings LLLC) to fabricate resin composite teeth with shades A4, A3.5, A3, A2, and A1 (Filtek Supreme Flowable Restorative, 3 M) and polished with a composite polishing kit (DiaComp Intra-Oral System, Brasseler USA, Savannah, GA, USA). Zirconia LVs with varying thicknesses and resin composite teeth with different shades were categorized into 15 groups, classified by both thickness and the underlying tooth shade, as detailed in Table 1.

2.2. Outcomes measured

A digital color imaging spectrophotometer (Spectroshade Micro II, SpectroShade USA, Oxnard, CA, USA) captured images of resin composite and zirconia LVs with varying thicknesses and shades (A1-A4) on the prepared teeth. Each image delineated the tooth contour along the LV borders, maintaining a 1.0 mm distance from the gingival area to eliminate pink color interference, as per software requirements. This spectrophotometer allowed direct measurement of the translucency parameter, known for its in vivo color measurement accuracy (Mehl et al., 2017). The software generated translucency maps and provided ΔE and ΔL color difference values for each image (Fig. 1).

Table 1
Summary of zirconia veneer thicknesses and background tooth shades in different groups.

		Shades				
		A1	**A2**	**A3**	**A3.5**	**A4**
Thickness						
	0.5 mm	Group 1 (0.5-A1)	Group 2 (0.5-A2)	Group 3 (0.5-A3)	Group 4 (0.5-A3.5)	Group 5 (0.5-A4)
	0.75 mm	Group 6 (0.75-A1)	Group 7 (0.75-A2)	Group 8 (0.75-A3)	Group 9 (0.75-A3.5)	Group 10 (0.75-A4)
	1.0 mm	Group 11 (1.0-A1)	Group 12 (1.0-A2)	Group 13 (1.0-A3)	Group 14 (1.0-A3.5)	Group 15 (1.0-A4)

2.3. Statistical analysis

To determine the required sample size for assessing the impact of zirconia veneer thickness and tooth shade on translucency, we conducted an a priori power analysis using G*Power software. With a large effect size of 0.8, an alpha error of 0.05, and a power of 0.8, the analysis indicated a need for 27 samples per group. Given this, we used 25 specimens per group, which was deemed adequate for addressing our research question and hypotheses. Statistical analysis was conducted using SPSS version 25 (IBM Corp., Armonk, NY, USA), focusing on mean color change (ΔE) and lightness (ΔL) across different thicknesses and shades. One-way ANOVA assessed significant differences, followed by a Tukey post hoc test for variations in thickness and shade groups. Significance was set at $\alpha = 0.05$.

3. Results

3.1. Influence of the thickness and tooth shade on the translucency values

The results of the zirconia LVs with different thicknesses over different tooth shade backgrounds are provided in Table 1. The two-way ANOVA analysis showed that the independent variables, shade and thickness or the interaction between them were statistically significant ($p = 0.00$) for the measured ΔE and ΔL values. Thickness had the most significant influence on the dependent variable, ΔE (partial eta squared $\eta P2 = 0.67$), followed by the interaction effect ($\eta P2 = 0.286$), and the independent variable of shade showed the lowest effect ($\eta P2 = 0.193$). A similar trend was observed for the dependent variable, ΔL, with the effect sizes for the thickness, interception, and shade of $\eta P2 = 0.27$, 0.23, and 0.18, respectively. The thickness of the material significantly affected the ΔE and ΔL. The lowest values were recorded for the samples that were 0.5 mm thick, while the highest values were observed for those 1.00 mm thick. No significant difference was observed between 0.75 mm and 1.00 mm thicknesses.

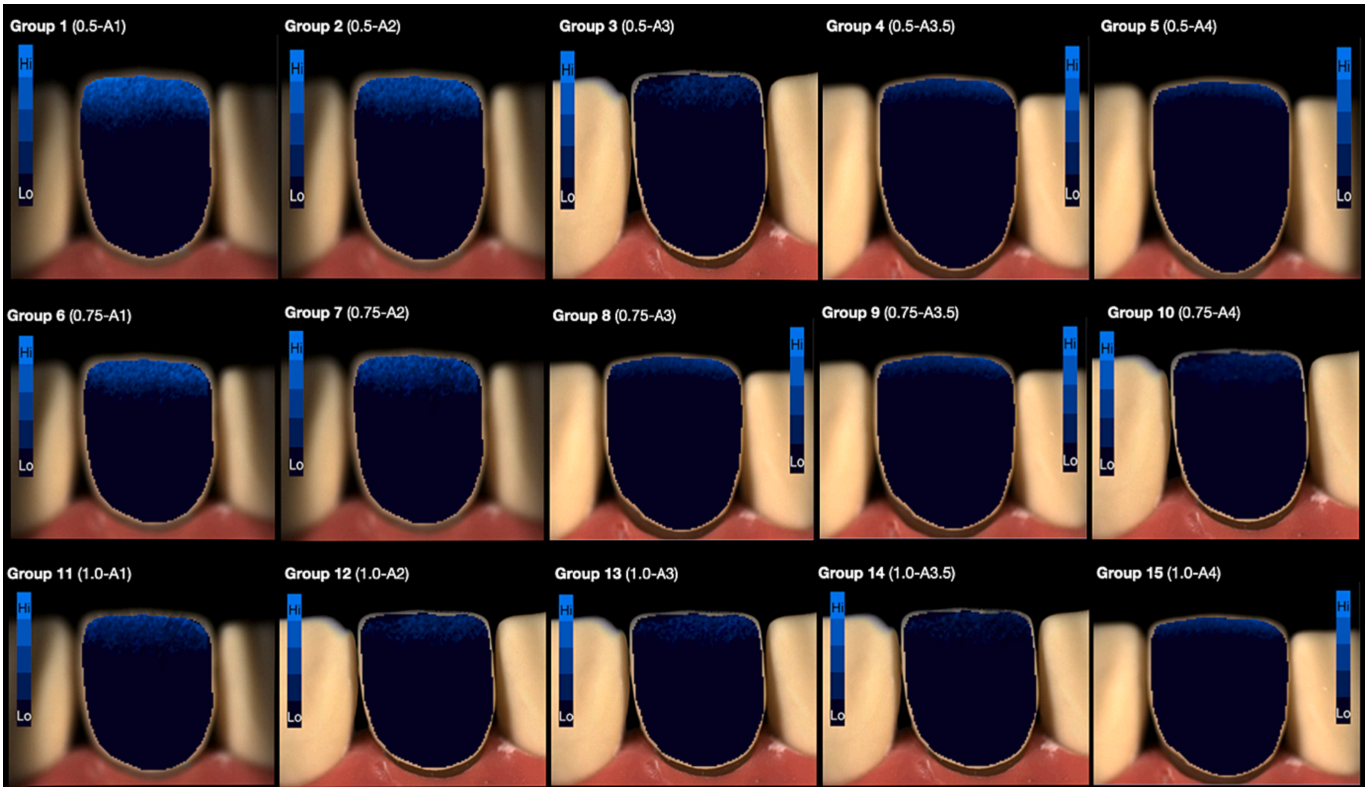

Fig. 1. Spectrophotometer captured images showing the translucency of zirconia veneers.

3.2. Effect of the tooth shade on the translucency variation

Different shades also had different impacts on ΔE and ΔL, as listed in Table 2. All restorations exhibited a certain amount of translucency modification (Table 2). LVs of 0.50 mm-thick paired with the A1 background had the least variation in ΔE and the highest value for translucency-lightness ΔL (1.86 ΔE; 1.32 ΔL), followed by A2 (2.36 ΔE; 1.28 ΔL) and A3 (2.36 ΔE; 1.67 ΔL); however, the values were similar across the following samples: Shades A3.5 (2.77 ΔE; 2.14 ΔL) and A4 (3.96 ΔE; 3.2 ΔL) had more variation and less translucency. Our results were similar for the 0.75 mm-thick LVs as follows: A1 (3.7 ΔE; 2.22 ΔL) and A2 (4.44 ΔE; 2.64 ΔL) showed the most negligible variation and highest translucency, followed by background A3 (4.6 ΔE; 3.15 ΔL) and A3.5 (5.17 ΔE; 3.25 ΔL), and A4 had the most variations and the least translucency-lightness (5.19 ΔE; 3.84 ΔL). The 1.0 mm LVs exhibited considerably more variation and lower translucency-lightness values but continued the trend of A1 (4.39 ΔE; 2.07 ΔL), A2 (4.73 ΔE; 2.27 ΔL) and A3 (4.81 ΔE; 2.28 ΔL). The backgrounds with A3.5 (4.82 ΔE; 2.38 ΔL) and A4 (5.29 ΔE; 2.72 ΔL) provided the most variation and lowest translucency-lightness values. These results are shown in Figs. 2 and 3.

Table 2
Summary of mean Delta E and Delta L values for different study groups.

Shade	Thickness	ΔE Mean (SD)	ΔL Mean (SD)
A1	0.5 mm	1.86 (0.96)^{B}	1.32 (0.91)^{E}
	0.75 mm	3.70 (0.67)^{C}	2.22 (0.87)^{AB}
	1.00 mm	4.39 (0.43)^{DE}	2.08 (0.61)^{AB}
A2	0.5 mm	2.36 (0.74)^{AB}	1.28 (0.86)^{E}
	0.75 mm	4.49 (0.59)^{DE}	2.64 (0.70)^{BC}
	1.00 mm	4.74 (0.62)^{EFG}	2.28 (0.86)^{AB}
A3	0.5 mm	2.36 (0.79)^{AB}	1.67 (0.89)^{AE}
	0.75 mm	4.60 (0.66)^{DEF}	3.15 (0.58)^{CD}
	1.00 mm	4.81 (2.01)^{EFG}	2.28 (0.48)^{AB}
A3.5	0.5 mm	2.78 (0.98)^{A}	2.15 (0.99)^{AB}
	0.75 mm	5.17 (0.58)^{FG}	3.25 (0.71)^{CD}
	1.00 mm	4.82 (0.22)^{EFG}	2.38 (0.38)^{AB}
A4	0.5 mm	3.96 (1.07)^{CD}	3.21 (0.87)^{CD}
	0.75 mm	5.20 (0.84)^{FG}	3.85 (0.77)^{D}
	1.00 mm	5.30 (0.30)^{G}	2.73 (0.52)^{BC}

SD, standard deviation. Same superscript capital letter indicates no statistically significant difference between groups in columns ($p > 0.05$).

4. Discussion

The results of the study indicate that the thickness and shade of composite teeth significantly impact the translucency of zirconia LVs. The hypothesis that thickness does not affect translucency was rejected, with LVs of 0.5 mm thickness displaying higher translucency than those of 0.75 mm and 1.0 mm. The null hypothesis that shade does not affect translucency was also rejected, with LVs on A1 and A2 background shades showing higher translucency than those on A3, A3.5, and A4 shades. To achieve higher translucency, it is recommended to use LVs of 0.5 mm thickness and A1 or A2 background shades.

Clinicians and dental technicians face the challenge of replicating nature in the esthetic zone using dental restorations because the ceramic needs to achieve optical results that are accepted by the patient (Jurado et al., 2022b; Kurt et al., 2020). Replication of the natural teeth properties in an LV is a process that requires assessment by either traditional visual assessment or digital devices. Traditional methods by the human eye may face difficulties such as clinician's experience, light conditions, eye's fatigue, and color blindness (Afrashtehfar, 2013; Lasser, et al., 2011). Novel devices such as digital spectrophotometers provide rapid objective and quantitative information that allows the clinician to digitally store and replicate the data as often as needed (Okubo et al.,

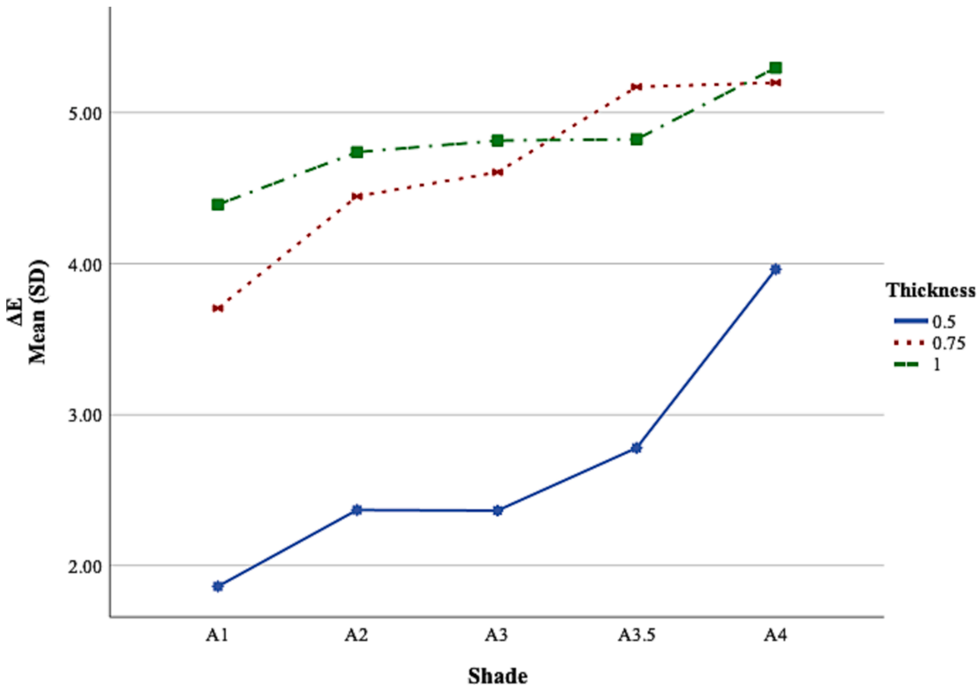

Fig. 2. Delta E values across all background tooth shades (line graph).

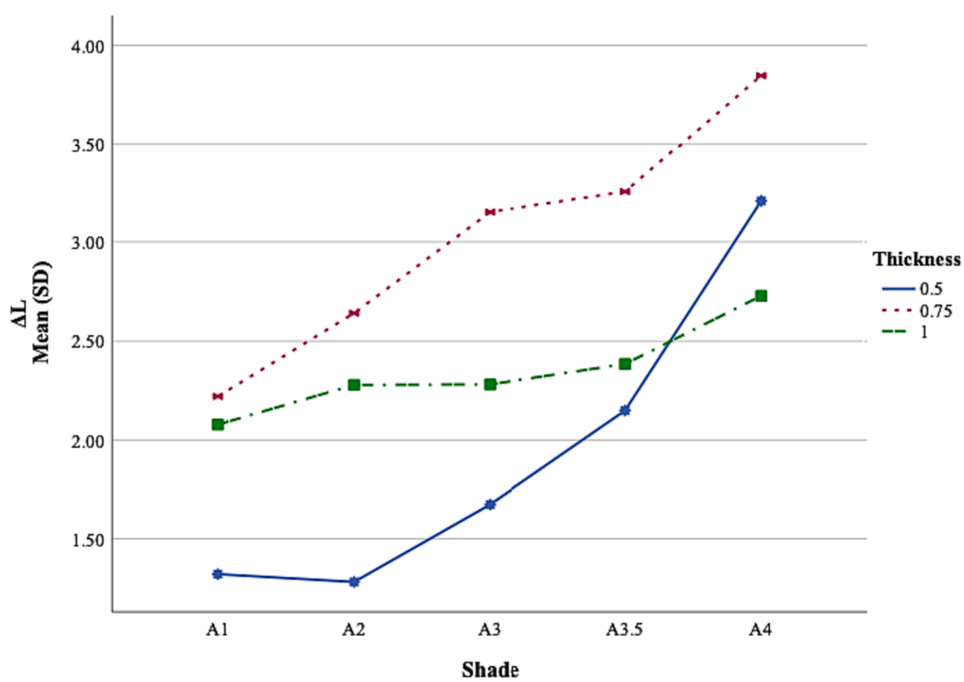

Fig. 3. Delta L values across all background tooth shades (line graph).

1998). For our study, we used the SpectroShade Micro, a digital color device that combines a digital camera and an LED spectrophotometer with an internal computer and its own analytical software. This device has an LCD touch color screen that can map the entire tooth surface or restoration, and the information can be transferred to a computer (Diamantopoulou et al., 2022; Kolakarnprasert et al., 2019). Harnessing combined digital and imaging technologies ensures precise, reproducible treatment planning for seamless rehabilitation execution (Alhammadi et al., 2021).

Dental spectrophotometers have proven their value in both clinical and in vitro studies examining the optical properties of natural dentition, ceramics, and soft tissues. For example, Du et al. (2012) employed a dental spectrophotometer to assess gingival color in the esthetic zone, finding it to provide precise and accurate results with minor color variations in the tissue. Paul et al. (2002) conducted a study on natural teeth and discovered that spectrophotometric shade analysis yielded a remarkable 93.3 % match in shade selection, surpassing the 26 % accuracy of visual shade selection. This indicates that spectrophotometric methods outperform traditional human evaluation in terms of accuracy and reproducibility. In a more recent study, Liberato et al. (2019) compared visual methods with intraoral scanners (IoS) and spectrophotometry for shade matching and concluded that instrumental methods, particularly spectrophotometry, are more reliable than visual techniques. The versatility of spectrophotometric equipment in dentistry is evident in numerous case reports, including its use in evaluating tooth whitening procedures (Ermis & Ugurlu, 2015), matching ceramics to natural teeth (Da Silva & Nagai, 2008), and assessing tooth defects that impact esthetic properties (Guerra et al., 2015).

The literature evaluating the translucency of zirconia LVs over different backgrounds is quite limited, and previous studies have mostly focused on flat samples rather than veneer-shaped samples. One study evaluated the translucency of flat samples of zirconia with 0.4 mm, 0.6 mm, and 1.0 mm thicknesses against white and black backgrounds using a digital spectrophotometer and concluded that the 0.4 mm flat sample provided the highest translucency (Al-Juaila et al., 2018). Another study evaluated the translucency of flat specimens of zirconia cores fabricated in shades A1, A2, and A3.5 with a 0.5 mm thickness and different veneering materials against white and black backgrounds using a spectrophotometer (Kurtulmus-Yilmaz & Ulusoy, 2014). The results indicated that, regardless of the shade of the core, the layered ceramic decreases the translucency of the restoration. The thicker the restoration, the less translucency was obtained. However, these studies evaluated flat specimens and did not use tooth shades as backgrounds. In contrast, our study used veneer-shaped specimens and resin composite teeth fabricated in different shades as backgrounds, which provide more clinically oriented results as they mimic real tooth shades. Overall, both studies concur with our results, displaying that LVs with less thickness provided higher translucency than thicker LVs.

The present study's results have shown a relationship between higher translucency and a background that is higher in value. When we arranged the traditional tooth shade guide Vita Classic by high to low value, the first tabs were B1, A1, B2, D2, A2, C1, C2, D4, A3, D3, B3, A3.5, B4, C3, A4, and C4. This same order was obtained for higher translucency when we tested our five background shades. However, it is important to note that a limited amount of available data specifically evaluates the translucency of zirconia veneers against tooth-shade backgrounds. One study evaluated the translucency of high, medium, and low-value resin composites that were used to replace enamel with different thicknesses (0.5 mm, 1.0 mm, 1.5 mm, 2.0 mm, 3.0 mm, and 4.0 mm) over white and other backgrounds (Schmeling et al., 2012). The results of this study showed that the composite resin translucency is affected by both the value and thickness, with high-value composite resins providing more translucency and the translucency decreasing as the specimen thickness increases. Another study evaluated the translucency parameters of eight different resin composites with 41 shades using a spectrophotometer and found that the translucency parameters are influenced by the shade of the composite used (Yu & Lee, 2008). The shades A1, A2, A3, A3.5, and B2 were found to have the highest translucency values. It is important to note that these studies used resin composites, not zirconia veneers. However, they concur with our study in that backgrounds with higher values provide higher translucency.

4.1. Limitations and future research

Translucency varied with zirconia veneer thickness and background shade. Optimal translucency (0.5 mm thickness) was observed with A1 and A2 backgrounds. To mitigate masking effects, full-contoured restorations against a black background simulated the oral environment, acknowledging associated limitations. The complexity of assessing masking effects arises from diverse techniques like porcelain veneering. Future studies might explore natural teeth backgrounds, considering associated variables. Additionally, evaluating various zirconia brands is pertinent, given the market's diverse options for clinicians and dental technicians.

5. Conclusions

The zirconia veneer translucency was influenced by both the veneer's thickness and the background tooth's shade. The translucency decreased as the veneer thickness or the tooth shade background became darker. The most translucent veneers were 0.5 mm thick with shades A1 or A2.

CRediT authorship contribution statement

Carlos A. Jurado: Conceptualization, Methodology, Investigation, Writing – original draft. **Abdulaziz Alhotan:** Investigation, Data curation, Writing – original draft. **Salwa Mekled:** Formal analysis, Validation, Visualization. **Seok-Hwan Cho:** Data curation, Writing – review & editing, Supervision. **Kelvin I. Afrashtehfar:** Conceptualization, Methodology, Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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