EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 71, 1555:1564, April, 2025

Print ISSN 0070-9484 • Online ISSN 2090-2360

EDJ
EGYPTIAN DENTAL JOURNAL

Fixed Prosthodontics and Dental Materials

Submit Date : 13-01-2025 • Accept Date : 22-02-2025 • Available online: 20-04-2025 • DOI : 10.21608/edj.2025.352603.3342

ASSESSMENT OF PHYSICAL PROPERTIES OF ZIRCONIA-BASED RESTORATIONS USING THREE DIFFERENT VENEERING TECHNIQUES

Abdelrahman Gamal Ahmed Abdelreheem Sanad [*], Cherif Adel Mohsen[**] *and* Mostafa El Houssieny Mohamed[***]

ABSTRACT

Objective: This study evaluated the effect of veneering techniques on the color and translucency of zirconia-based restorations. **Materials and Methods:** In this study, three commercially available glass ceramic materials were utilized: IPS e.max CAD, IPS e.max Zirpress, IPS e.max Ceram powder (all from Ivoclar Vivadent). The three materials were applied to create a veneering layer over the Zirconia Frameworks (IPS e.max Zir CAD Prime) from Ivoclar Vivadent), to produce samples in the form of plates with ceramic discs. These samples were then analyzed to assess color and translucency (TP). A total of sixty samples were constructed. The samples were divided into three equal groups; Group A: Cad on Technique (n=20) Group B: Press Over Technique (n=20) Group C: Traditional Layering technique (n=20). Each group was divided into 3 subgroups according to the type of test. Subgroup (1) color assessment (n=10). Subgroup (2): translucency assessment (n=10). A spectrophotometer was used to measure color parameters (L*, a*, b*) and total luminous transmittance (τ) of the specimens for calculation of (TP) and (ΔE). One-way analysis of variance (ANOVA) test combined with Post hoc test were used to analyze the data ($\alpha = 0.05$) **Results:** The CAD - On technique group had the lowest ΔE values (1.14±0.29), Followed by the press-over group (2.60±0.51), The highest ΔE value (4.22±0.26) was seen in the Layering technique group. A significant statistical difference was observed among the three groups ($P > 0.05$). For translucency (TP), the Press over technique had the highest mean value (6.05 ± 0.32) followed by the layering technique (5.56 ± 0.27) and then CAD On technique (5.15 ± 0.33). There was a significant difference between the three techniques and the difference between groups was statistically significant. ***P value < 0.05*. Conclusions:** Within the limitations of this study, the outcomes can be summarized as follows: The layering technique exhibited the greatest color mismatch when compared to the color scale, while the CAD ON technique demonstrated the most accurate color match. The samples veneered with layering and press-over techniques exhibited higher translucency compared to those made with the CAD-ON veneering technique

KEYWORDS: Translucency, Zirconia veneered ceramics, Ceramic-fixed prostheses.

* Assistant lecturer of Fixed Prosthodontics, Faculty of Dentistry, Deraya University, Minya, Egypt.
** Professor of Fixed Prosthodontics Dept., Faculty of Dentistry, Minia University, Minya, Egypt.
*** Lecturer of Fixed Prosthodontics Dept., Faculty of Dentistry, Minia University, Minya, Egypt.

INTRODUCTION

Zirconia restorations are widely used in dentistry because of their superior mechanical strength and biocompatibility. However, one aesthetic drawback of zirconia is its opacity, which makes it challenging to achieve a natural look and proper shade matching in restorations.[1] This opacity is primarily attributed to zirconia's high refractive index, resulting in reduced transparency in both the visible and infrared light ranges.[2] The success of zirconia-based restorations is heavily dependent on the interaction between the zirconia core and the veneering material. With the evolution of ceramic materials, new techniques for veneering zirconia have emerged alongside traditional methods such as the layering technique, the pressing (press-over) technique, and the CAD-ON technique, also known as file splitting.

Therefore, the veneering of zirconia is a crucial aspect in achieving color matching with natural teeth by replicating their translucency and hue. While the zirconia core provides exceptional strength, the veneering material is vital to the overall success of the restoration, as it significantly impacts both its aesthetic appearance and functional performance.

The porcelain powder and modeling liquid are mixed according to the recommended ratio by the manufacturer and applied in a thin layer to the zirconia core, slightly larger than the desired final dimensions to compensate for porcelain shrinkage.[3]

The press-over technique involves the use of fluorapatite glass-ceramic material in the form of pressable ingots, which are melted and pressed into a prepared wax pattern of the veneering layer over the zirconia framework using a heat-press furnace.[4]

Advancements in computer-aided design and computer-aided manufacturing (CAD/CAM) have made it possible to produce veneering ceramics using a technique called "file-splitting" (CAD-ON), which employs a fusion glass-ceramic material to bond zirconia to the superstructure. It is still unclear if various veneering procedures affect the aesthetics of all-ceramic restorations to the same extent.[5]

Translucency describes a material's capacity to allow light to pass through, while also scattering, reflecting, or transmitting part of it. Materials with higher translucency permit more light to pass through, leading to a more lifelike and authentic look. In dental ceramics, translucency is regarded as an essential characteristic because it influences the aesthetic result, making the restoration appear more like natural teeth. Increased translucency in ceramics improves their harmony with surrounding dental tissues and enhances the overall visual appeal of the restoration. Numerous studies emphasize the importance of translucency when designing ceramic restorations for optimal aesthetic results.[6,7]

Spectrophotometers are considered the most accurate tools for colour measurement. This instrument measures the spectral reflectance of an object and represent it using three coordinates (L^*, a^*, b^*) that define the colour within the CIE Lab* colour space. The CIE recommends employing CIELAB parameters to determine the colour differences (ΔE).[8]. However, the optimal zirconia veneering technique for achieving the best aesthetic outcomes has not yet been determined. Consequently, additional studies are required to measure the colour compatibility of zirconia when using different veneering methods.

This study aimed to investigate the effects of three different veneering techniques on the color and translucency of veneered zirconia ceramics. This study's null hypothesis stated that the color and translucency of the zirconia veneered crowns would be unaffected by the veneering technique.

Sample Size Calculation:

The sample size calculation for this study was based on previous research [9] and utilized an effect size of 0.72, an 80% power level, and a significance level (alpha) of 0.05. The calculations were performed using G*Power 3.1.9.7 software, which is designed for one-way ANOVA and post hoc tests.

As a result, a total of ten specimens (N=10) were determined to be necessary for each group according to the sample size estimation.

MATERIALS AND METHODS

This study employed three commercially available glass ceramic materials: fluorapatite glass-ceramic IPS e.max ZirPress (Ivoclar Vivadent), lithium disilicate glass-ceramic IPS e.max CAD (Ivoclar Vivadent), low-fusing nano-fluorapatite dentin porcelain IPS e.max Ceram powder, liquid (Ivoclar Vivadent) and IPS e.max Zir CAD Prime zirconia (Ivoclar Vivadent)shade A3, a partially sintered zirconium oxide stabilized with yttrium oxide. In total, sixty zirconia plate samples veneered with ceramic discs were constructed utilizing three different veneering techniques. The samples were divided into three equal groups; Group A: Cad on Technique (n=20), Group B: Press Over Technique (n=20), and Group C: Traditional Layering technique (n=20). Each group was divided into 3 subgroups according to the type of test. (n=10). Subgroup (1) translucency analysis and Subgroup (2) color analysis.

Samples Preparation:

The zirconia block was cut using a low-speed slicing machine (Isomet, Buehler, USA) under running water to produce samples with a thickness of 0.65 ± 0.01 mm. The zirconia plates were initially cut 20% larger than the required dimensions to account for the shrinkage during sintering. The samples were then fired at 1500°C for 7 hours in a Mihm Vogt Tabeo Dental Sintering Furnace (Tabeo-1/M/ZIRKon-100 , Germany) to form square plates (10 mm × 10 mm) with a final thickness of 0.5 ± 0.01 mm. A digital caliper (Pittsburgh, Camarillo, CA, USA) was used to confirm the dimensions by measuring five different locations on each sample. Discs of IPS e.max CAD were fabricated from an IPS e.max CAD block using the same technique, but with a 0.5 mm diameter and 0.5 mm thickness, to be fused with the zirconia plates for the CAD-on-veneering technique. Also Wax pattern for press over group were cut from wax block (Sagemax Bioceramics, Inc. USA) using the low speed slicing machines to produce discs with the same previous dimensions. As a result, three different superstructure materials were fabricated with 5 mm diameters and 0.5 mm thickness for press over, Cad on technique and porcelain build up for layering technique. (N=10 in each group)

For the CAD-on technique, a fusion glass-ceramic material (IPS e.max CAD Crystall/Connect) was applied on the center of the zirconia plates and the IPS e.max CAD disc to facilitate the attachment of the two materials. The entire restoration was then placed in the tray, and the crystallization/fusion firing program was initiated in the EP3010 furnace (Ivoclar Vivadent) to fully crystallize and fuse the samples. (**Figure 1)**

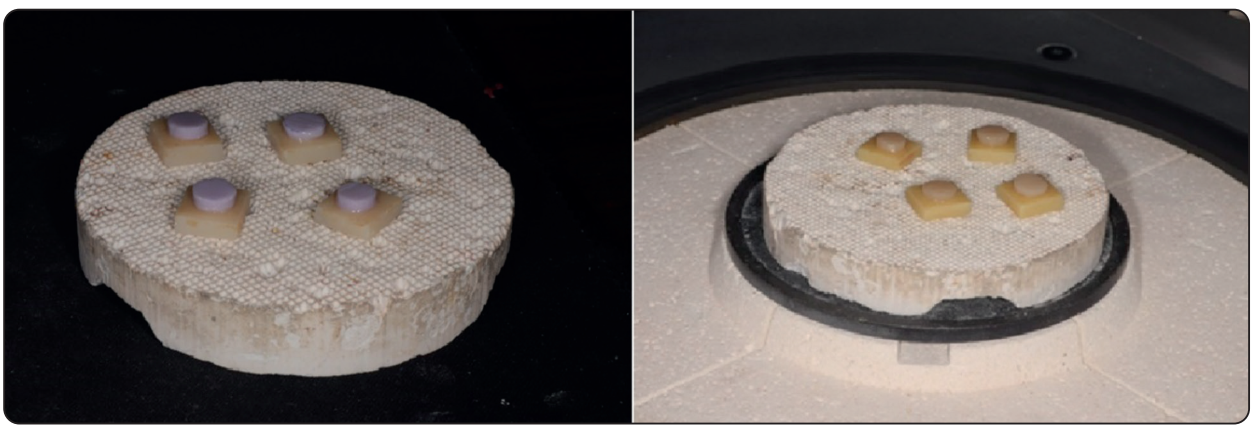

Fig. (1) Samples of Cad on technique before and after fusion/crystallization cycle

For press-over and layering groups the fusion material was IPS e.max ZirLiner that was applied with a thickness that did not exceed 0.1 mm and left to dry and fired.

In the press-over group, the wax pattern was attached to the zirconia in the area of the Zirliner using a drop of heated wax and then secured to the IPS silicon investment ring system with sprue wax. Bellavest® SH Investment (Bego , Germany) was used as the investment material, and the ring was placed in a burnout furnace (Renfert,USA) at 850°C for 20 minutes. Afterward, the ingot (IPS e.max ZirPress, Ivoclar Vivadent) was inserted into the hot ring with a plunger in the pressing furnace (EP3010, Ivoclar Vivadent), and the program was initiated according to the manufacturer's instructions. Once the program was completed, the ring was allowed to cool down. The samples were finished and polished to a final thickness of 1.0 ± 0.01 mm.

For the layering technique, IPS e.max Ceram Dentin A3 (Ivoclar Vivadent) was mixed with the IPS e.max modeling liquid and was built up in layers to the entire surface of the ZirLiner. The second dentin layer was applied to adjust and compensate for the shrinkage of the porcelain. The samples were finished and polished and the thickness was then verified and measured with a digital caliper, confirming it to be 1.00 ± 0.01 mm, then glazing was done with IPS e max glaze according to firing parameters of each veneering material.

The veneering surface of all specimens was finished and polished using white silicon and grey rubber discs (Shenzhen Upcera Dental Technology Co., Ltd.China), with the same operator carrying out the procedure to maintain uniformity.

Evaluation of Color Difference

The evaluation of color parameters was determined using the CIELab system of color using a spectrophotometer Cary 5000 Spectrophotometer provided by Agilent Technologies (USA) certified to ISO 9001. The color of the central area of the A3 shade tab was recorded, and the color difference (ΔE) was determined using the following formula: $\Delta E = [(\Delta L^2 + \Delta a^2 + \Delta b^2)]$ ½. Here, ΔE represents the color difference between the A3 shade tab and the measured sample, while ΔL denotes the change in lightness, and Δa^* and Δb^* correspond to the differences in chroma values between the shade tab and the sample.

Evaluation of Translucency Parameters

The Translucency Parameter (TP) was calculated by determining the color difference of each specimen against white (W) and black (B) backgrounds using spectrophotometry. TP was assessed based on the CIE Lab* color scale. Each specimen was placed in the spectrophotometer for translucency testing across the visible spectrum, with wavelengths ranging from 380 to 780 nm. Three measurements were taken for each specimen, with the angle of incidence set at 0/0, and readings were recorded at 10 nm intervals between 0° and 15°. The measurements were performed using the following equation: $TP = [(L^*_B\text{-}L^*_W)2 + (a^*_B\text{-}a^*_W)2 + (b^*_B\text{-}b^*_W)2]^{1/2}$ where *TP*: translucency, *B,w*: measurements against black and white backgrounds respectively. *l,a,b*: CIElab measurements l* refers to the brightness, a* refers to greenness, and b* refers to blueness.[9]

The TP values for direct transmittance were imported into Microsoft Excel for quantitative analysis. The final transmittance represents the total luminous transmittance within the visible spectrum for each specimen. One-way ANOVA and post hoc analysis were conducted to compare the TP values between the groups .

Statistical analysis

The data were analyzed statistically using one-way ANOVA for all groups ($\alpha = 0.05$, SPSS 11.0 for Windows; Chicago, IL). P-values below 0.05 were considered statistically significant in all tests. 0.05

RESULTS

The color difference (ΔE) values for the samples are presented in **(Table 1).** The CAD-on technique group had the lowest average ΔE of (1.14±0.29), which was statistically significantly different from the other groups. The highest ΔE value of (4.22±0.26) was seen in the Layering technique group. A significant statistical difference was observed among the three groups (P > 0.05) **(Table 1). (Figure 2)**

For translucency (TP), the press-over technique had the highest mean value (6.05 ± 0.32) followed by layering (5.56 ± 0.27) then CAD On technique (5.15 ± 0.33) and there was a significant difference between the three techniques. ***P value < 0.05.*** **(Table 2) (Figure 3)**

TABLE (1) **ΔE** values by One way ANOVA test; *Significant level at P value < 0.05*

ΔE	**Technique**			***P-value***
	Layering technique	**Press over technique**	**CAD on technique**	
Range	3.87-4.72	2.05-3.48	0.80-1.54	
Mean ±SD	4.22±0.26	2.60±0.51	1.14± 0.29	<0.0001

TABLE (2) **TP values** by One way ANOVA *test; Significant level at P value* < 0.05

TP	**Technique**			***P-value***
	Layering	**Press Over**	**CAD on**	
Range	5.13-5.98	5.66-6.65	4.76-5.68	
Mean ±SD	5.56 ± 0.27	6.05 ± 0.32	5.15 ± 0.33	< 0.0001

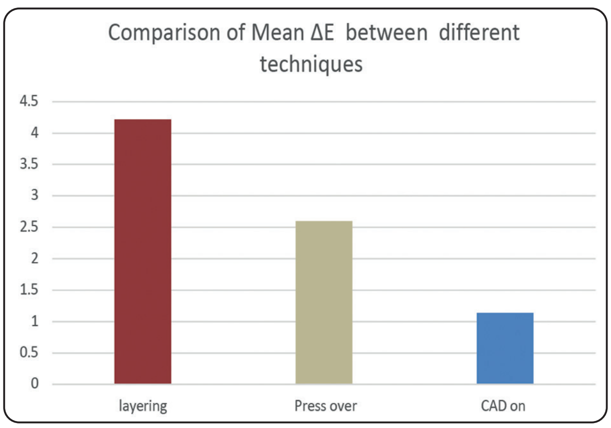

Fig. (2) Bar Chart representing Mean and SD of ΔE Values for Three veneering technique

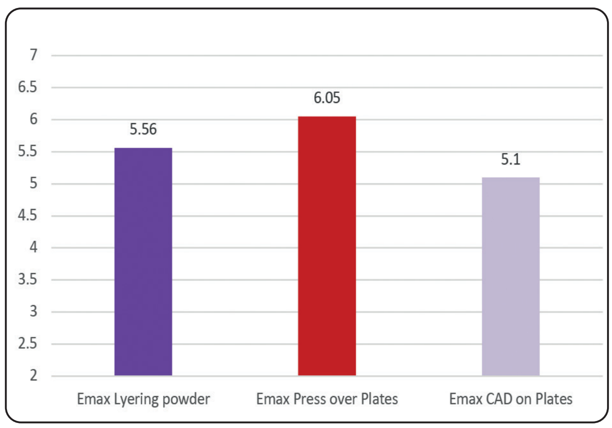

Fig. (3) Bar Chart representing Mean and SD of TP Values for Three veneering technique

DISCUSSION

Zirconia restorations exhibit superior mechanical properties and improved fracture resistance In comparison to other traditional dental ceramics [10], its superior flexural strength (exceeding 1000 MPa) makes it ideal for applications in both the anterior and posterior areas of the mouth. [11] However, the opacity of zirconia restricts the achievement of the ideal aesthetic appearance.

To choose the best veneering technique, clinicians and technicians need to know the aesthetic properties of each veneering method. In our study, the effect of production techniques on the final colour and translucency of zirconia veneered restorations was examined

This study utilized a shaded zirconia core to achieve a more lifelike appearance, closely resembling the opaque yellow dentin beneath a translucent enamel layer.[12] Layering technique is considered a sensitive technique because it is completely handmade with the brush and needs many firing cycles with finishing and polishing steps in between.[13]

Press over technique is a recent technique that was introduced as an alternative to the layering technique due to its accuracy and to overcome cohesive failure.[14] The core with the veneering wax patterns can be tried intraorally to allow adjustment to the final shape before pressing. However, its optical properties are still questionable [15].

Recently, CAD on veneering technique was introduced in which zirconia core and Veneering ceramics are produced digitally and fused with different materials.

Various veneering materials and methods lead to noticeable differences between the final restoration shade and its corresponding shade tab [16,17]. When IPS Emax Ceram is applied using the layering technique, it is distinguished by its consistency in shape and color stability, even after several firing cycles, resulting in a unique blend of translucency, brightness, and opalescence [9].

Compatible zirconia core and veneering materials were selected to ensure that their coefficients of thermal expansion were compatible. To make sure the restorations look and feel just like real teeth, the dentin porcelain used in the layering procedure has nano-fluorapatite crystals that are comparable to the ones found in healthy teeth. The restorations' translucency, opalescence, and brightness are controlled by the interaction between the various-sized fluorapatite crystals.

The ceramic plates and discs were cut using a diamond saw operating at a low speed while being cooled by water. [14,18] To compensate for the 20% percent shrinkage that occurred during sintering, zirconia blocks were cut into 0.63 ± 0.01-millimeter plates to achieve the necessary thickness of 0.5 ± 0.01 millimeters.[19]

In the CAD-ON technique, a strong bond between the zirconia and the Veneering material was achieved by using IPS Emax CAD Crystall. /Connect, low-fusing glass ceramic for veneering. This was done because the ceramic has thixotropic behavior, a sintering temperature that has been adjusted to the crystallization temperature of IPS Emax CAD (840-850 °C), and a coefficient of thermal expansion of $9.2 \times 10{-}6/k$, which is suitable for both zirconia and IPS Emax CAD. [20].

IPS e.max Zirliner was used for veneering with Layering and press-over techniques, to enable a strong connection with the zirconia core and to get the desired translucency and enhanced fluorescence. [21,22].

All specimens were polished and glazed to create a smooth glossy surface necessary for measurements and to mimic clinical conditions. [23].

The success of the layering technique depends on a lot of technique-sensitive factors, such as the type of porcelain powder and liquid, the operator's experience, the quality of the porcelain mixture, the firing and cooling cycle, the number of firings, and the ceramic shrinkage. [24,25,26].

The (CAD-on) veneering method was introduced as a more reliable method because of the benefits of the CAD/CAM system including better fitness and rapid processing.

IPS e.max Ceram, when employed in the layering technique, maintains excellent shape and color stability even after multiple firing cycles, allowing for a distinctive blend of translucency, brightness, and opalescence [9].

For the layering technique, IPS Emax Ceram A3 was used, whereas IPS e.max ZirPress LT A3 was selected for the press-over technique, and IPS Emax CAD LT A3 was employed for the CAD-on technique. All of these materials were compared to the A3 shade from the Vita Classic shade guide (the target color) for all the samples [27] in this study, the thickness of the zirconia core was 0.5 mm which is the minimum thickness for full crowns. The veneer thickness used in the present study was 0.5 mm as recommended [28].

The veneering surface of all specimens was finished and polished using white silicon and grey rubber discs (Shenzhen Upcera Dental Technology Co., Ltd.China), with the same operator carrying out the procedure to maintain uniformity. A smooth surface was created to enable direct contact between the spectrophotometer's tip and the surface without any angular distortion [29]

Spectrophotometers measure the light energy reflected from an object at intervals of 1-25 nm along the visible spectrum.[30] These devices can identify and measure small colour variations, with their sensitivity to monochromatic samples in laboratory conditions typically being 0.1 ΔE units [31]

Various studies have attempted to establish an acceptable ΔE limit, though differences in their findings have been observed. **Seghi et al. (1986)** identified a color difference threshold of ΔE = 2, while **Ragain et al. (2001)** suggested that an average CIE Lab* color difference of $\Delta E = 3.7$ is typical for a color match in the oral environment [32, 33] **Khashayar et al. (2014)** [34] found the majority of studies set the perceptibility threshold at $\Delta E = 1$ and the that ΔE value of 3.7 represents the threshold at which half of the observers accept the color difference. This ΔE value has been widely cited in subsequent research and served as the reference point for the current study.

The results of this study indicated a significant difference among the three techniques. The mean ΔE value for the layering technique was 4.22, which is considered above the perceptible threshold, while the press-over technique had a mean ΔE value of 2.60, and the CAD-on group had a mean ΔE value of **1.14**

The findings are consistent with the study by **Ugur M & Kavut I (2021)** [35], which reported that the layering technique showed the most noticeable color discrepancy when compared to the color scale, with the press-over technique following behind, and the CAD-on technique achieving the closest match.

These findings contradict those of **Zhang et al. (2008)** [21], who reported that Zirconia veneered with the layering technique closely matched the standard shade tab, with a minimal color difference, while the press-over technique showed the greatest color disparity. The results of the current study may be attributed to differences in the materials used for the heat-pressing and layering techniques. Specifically, the IPS emax zirpress for heat-pressing and IPS emax Ceram for layering vary in their structure, homogeneity, porosity, volume, and pigment content. As a result, variations in the Lab* values were observed

These results also differ from those of **Mahrouse, A. et al**. **(2014)** [36]**,** who concluded that the layering technique provided the best color match, while the press-over technique yielded the worst results. In their study, the press-over technique had a **ΔE** value of 4.23, considered above the noticeable threshold, while the layering technique showed a **ΔE** of 3.73, which was within the perceptible range, with no statistically significant difference between the two groups.

The mean total transmittance (TP) values for the three techniques were as follows: press-over veneering (6.05), layering (5.56), and CAD-ON (5.15). The current study's findings corroborate those of **El-Agway et al. (2018)** [9], who found that zirconia veneered by layering and press-over methods resulted in higher translucency restorations compared to those veneered with the CAD-On technique.

The results are consistent with those of **Clarke** [37]**,** who found that material composition plays a key role in translucency. Materials with smaller particles tend to be more translucent, as light passes through them with less refraction and absorption, despite increased scattering due to the higher particle count. In contrast, larger particles result in greater light reflection, refraction, and absorption. The translucency of the layering technique is higher than that of the press-over technique because the Nano-fluorapatite particles in IPS Emax Ceram are smaller than the fluorapatite particles in IPS Emax ZirPress. Additionally, the translucency of the CAD-On technique is lower than both the layering and press-over techniques, as the lithium disilicate particles in IPS Emax CAD are larger than the fluorapatite and Nano-fluorapatite particles.

The researchers proposed that differences in the translucency of the zirconia framework veneer ceramic system are primarily driven by factors such as the crystal microstructure of the veneering material, including aspects like crystal volume, refractive index, and particle size. Other contributing factors include the material's homogeneity, the number of firing cycles, and the arrangement of particles within the matrix, all of which influence the extent of light scattering. [38, 39]

Luo and Zhang (2010) [22] assessed the light transmittance of different veneering techniques in zirconia-based restorations and discovered that the press-over technique exhibited the highest translucency, while the cut-back technique demonstrated the lowest. They attributed this to factors such as the porcelain/powder ratio, vibration, condensation method, and firing temperature, which can result in undesirable particle growth. These factors contribute to uneven crystal distribution and irregular crystal growth.

The arrangement and composition of crystals can differ between the layering and pressing methods. As a result, light is reflected at the interface, leading to a reduction in translucency in core-veneer systems made with different techniques. This observation aligns with the findings of our study.

A limitation of this study is that it was conducted under in vitro conditions, which may not fully replicate the conditions found in the oral cavity. Additional research is required to explore the impact of resin cement, the surface color of the restoration, and various surface treatments on the translucency of zirconia-based ceramics

Based on the results obtained, the hypothesis was rejected as there was a significant difference in color and translucency between different veneering techniques.

CONCLUSIONS

Within the limitations of the present study, the outcomes can be summarized as follows:

1. The layering technique displayed the greatest color mismatch with the color scale, while the CAD ON technique provided the most accurate color match.
2. The samples veneered with layering and press-over techniques exhibited higher translucency compared to those made with the CAD-ON veneering technique

REFERENCES

1. Tuncel, İ., Turp, I., & Üşümez, A. (2016). Evaluation of the translucency of monolithic and framework zirconia materials. Journal of Advanced Prosthodontics, 8(3), 181-186.

2. Vagkopoulou, T., Koutayas, S.O., Koidis, P., & Strub, J.R. (2009). Zirconia in dentistry: Part 1. Understanding the nature of this emerging bioceramic. European Journal of Esthetic Dentistry, 4(2), 130-151.

3. Ishibe, M., Raigrodski, A.J., Flinn, B.D., Sorrentino, R., & Spear, F. (2011). Shear bond strengths of pressed and layered veneering ceramics to high-noble alloy and zirconia cores. Journal of Prosthetic Dentistry, 106(1), 29-37.

4. Rosentritt, M., Behr, M., & Reich, S. (2011). Influence of fabrication processes on the in vitro performance of fixed dental prostheses with zirconia substructures. Clinical Oral Investigations, 15(6), 1007-1012.

5. Ertürk, K., Cömlekoğlu, B., Dündar Çömlekoğlu, M., Özcan, M., & Güngör, M. (2014). Effect of veneering methods on zirconia framework-veneer ceramic adhesion and fracture resistance of single crowns. Journal of Prosthodontics, 24(T1-T12).

6. Heffernan, M.J., Aquilino, S.A., Diaz-Arnold, A.M., & Haselton, D.R. (2002). Relative translucency of six all-ceramic systems: Part I, Core materials. Journal of Prosthetic Dentistry, 88(1), 4-9.

7. Lee, Y.-K., Cha, H.-S., & Ahn, J.-S. (2007). Layered color of all-ceramic core and veneer ceramics. Journal of Prosthetic Dentistry, 97(5), 279-286.

8. Bubteina, N., Mohamed, R., & Mohamed, S. (2017). Comparison between two ceramic veneer materials in their color and translucency before and after applying luting agent layer. Libyan Journal of Science & Technology, 6, 1-4.

9. Badr El-Agwany, M.A.M., Wahsh, M.M., & Morsi, T.S. (2018). Effect of veneering techniques and subsequent aging on translucency of bilayered zirconia. Future Dental Journal, 4(2), 274-278.

10. Miyazaki, T., Nakamura, T., Matsumura, H., Ban, S., & Kobayashi, T. (2013). Current status of zirconia restoration. Journal of Prosthodontic Research, 57(4), 236-261.

11. Filser, F.T. (2001). Direct ceramic machining of ceramic dental restorations. Dental Materials, 17(2), 89-106.

12. Shah, K., Holloway, J.A., & Denry, I.L. (2008). Effect of coloring with various metal oxides on the microstructure, color, and flexural strength of 3Y-TZP. Journal of Biomedical Materials Research - Part B: Applied Biomaterials, 87, 329-337.

13. Holland, W., Schweiger, M., Frank, M., & Rheinberger, V. (2000). A comparison of the microstructure and properties of the IPS Empress 2 and the IPS Empress glass ceramics. Journal of Biomedical Materials Research, 53, 297-303.

14. Aboushelib, M.N., Kleverlaan, C.J., & Feilzer, A.J. (2006). Microtensile bond strength of different components of core veneered all-ceramic restorations: Part II, Zirconia veneering ceramics. Dental Materials, 22, 857-863.

15. Miyazaki, T., Nakamura, T., Matsumura, H., Ban, S., & Kobayashi, T. (2013). Current status of zirconia restoration. Journal of Prosthodontic Research, 57(4), 236-261.

16. Crespin, B.J., Hewlett, E., & Seghi, R. (1991). Relative color stability of ceramic stains subjected to glazing temperatures. Journal of Prosthetic Dentistry, 66, 20-23.

17. Jorgenson, M.W., & Goodkind, R.J. (1979). Spectrophotometric study of five porcelain shades relative to the dimension of color, porcelain thickness, and repeated firings. Journal of Prosthetic Dentistry, 42, 96-105.

18. Kim, H.J., Lim, H.P., Park, Y.J., et al. (2011). Effect of zirconia surface treatments on the shear bond strength of veneering ceramic. Journal of Prosthetic Dentistry, 105, 315-322.

19. Gye-Jeong, O., Kwi-Dug, Y., Kwang-Min, L., Hyun-Pil, L., & Sang-Won, P. (2010). Sintering behavior and mechanical properties of zirconia compacts fabricated by uniaxial press forming. Journal of Advanced Prosthodontics, 2, 81-87.

20. Galloway, H., Lu, W., Liu, J., & Zhang, S. (2019). Thixotropic behavior and sintering parameters in dental ceramics. Journal of Materials Science, 54(12), 3541-3552.

21. Luo, X.P., & Zhang, L. (2010). Effect of veneering techniques on color and translucency of Y-TZP. Journal of Prosthodontics, 19, 465-470.

22. Florian, B., Josef, S., Marlis, E., Heinrich, F., Wolfgang, G., & Daniel, E. (2009). High-strength CAD/CAM-fabricated veneering material sintered to zirconia copings: A new fabrication mode for all-ceramic restorations. Dental Materials, 25, 121-128.

23. Sjögren, G., Lantto, R., Granberg, A., Sundström, B.O., & Tillberg, A. (1999). Clinical examination of leucite-

reinforced glass ceramic crowns (Empress) in general practice: A retrospective study. International Journal of Prosthodontics, 12, 122-1282.

24. Stawarczyk, B., Ozcan, M., Roos, M., et al. (2011). Load-bearing capacity and failure types of anterior zirconia crowns veneered with overpressing and layering techniques. Dental Materials, 27, 1045-1053.

25. Anusavice, K.J., Kakar, K., & Ferree, N. (2007). Which mechanical and physical testing methods are relevant for predicting the clinical performance of ceramic-based dental prostheses? Clinical Oral Implants Research, 18, 218-231.

26. Eisenburger, M., Mache, T., Borchers, L., et al. (2011). Fracture stability of anterior zirconia crowns with different core designs and veneered using the layering or press-over technique. European Journal of Oral Sciences, 119, 253-257.

27. Iravani, M., Shamszadeh, S., Panahandeh, N., Sheikh-Al-Eslamian, S.M., & Torabzadeh, H. (2020). Shade reproduction and the ability of lithium disilicate ceramics to mask dark substrates. Restorative Dentistry & Endodontics, 45(3), e41.

28. Heffernan, M.J., Aquilino, S.A., Diaz-Arnold, A.M., Haselton, D.R., Stanford, C.M., & Vargas, M.A. (2002). Relative translucency of six all-ceramic systems: Part II, Core and veneer materials. Journal of Prosthetic Dentistry, 88, 10-15.

29. Sarac, D., Sarac, Y.S., Yuzbasioglu, E., & Bal, S. (2006). The effects of porcelain polishing systems on color and surface texture of feldspathic porcelain. Journal of Prosthetic Dentistry, 96, 122-128.

30. Khurana, R., Tredwin, C.J., Weisbloom, M., & Moles, D.R. (2007). A clinical evaluation of the individual repeatability of three commercially available color measuring devices. British Dental Journal, 203, 675-680.

31. Seghi, R.R., Johnston, W.M., & O'Brien, W.J. (1986). Spectrophotometer analysis of color differences between porcelain systems. Journal of Prosthetic Dentistry, 56, 35-40.

32. Seghi, R.R., Johnston, W.M., & O'Brien, W.J. (1989). Performance assessment of colorimetric devices on dental porcelains. Journal of Dental Research, 68(12), 1755-1759.

33. Regain, J.C., & Johnston, W.M. (2001). Minimum color differences for discriminating mismatch between composite and tooth color. Journal of Esthetic Restorative Dentistry, 13, 41-48.

34. Khashayar, G., Bain, P., Salari, S., Dozie, A., Kleverlaan, C.J., & Feilzer, A.J. (2014). Perceptibility and acceptability thresholds for color differences in dentistry. Journal of Dentistry, 42, 637-644.

35. Ugur, M., & Kavut, I. (2021). Effect of different manufacturing techniques on color in zirconia-based all ceramics. Dental Medicine Research, 9, 68-72.

36. Mahrouse, A., Anwar, E., & Sallam, H. (2014). Effect of veneering thickness and technique on color and strength of shaded zirconia core veneered ceramic. Egyptian Dental Journal, 60, 937-951.

37. Clarke, F.J., & McLean, J.W. (1983). Measurement of color of human teeth. Quintessence International, 14(6), 441-490

38. Turgut, S., & Bagis, B. (2011). Color stability of laminate veneers: An in vitro study. Journal of Dentistry, 39(Suppl 3), e57-64.

39. Kim, I.J., & Lee, Y.K. (2007). Changes in color and color parameters of dental resin composites after polymerization. Journal of Biomedical Materials Research B: Applied Biomaterials, 80, 541-546