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Original article

Effect of Veneering Technique on Color Matching of Translucent Ice Zirconia Substructure Veneered with Lithium Disilicate Using Pressable Technique Versus Conventional Layering Technique: An *In-Vitro* Study

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ABSTRACT

Aim**. This study evaluated the effect of different veneering techniques on the color of translucent Ice zirconia substructure.* ***Methods. *A total of twenty translucent Ice Zirconia disc samples 12 mm in a diameter, 0.5 mm in thickness were designed and constructed using zirkonzahn system. The samples were classified into two groups: Group I: (n = 10) veneered by layering technique using IPS emax Ceram 1.0 mm thickness, dentin shade A2. Group II (n = 10) veneered by press-on technique using IPS emax press in-got 1.0 mm thickness, shade A2. Twenty composite resin discs 12mm in diameter and 5mm in thickness in A3 shade, were fabricated to be bonded to ceramic specimens using Dual-curing translucent rely X Unicem automix Self-Adhesive Resin luting cement. The color measurement was done using a spectrophotometer unit and ΔE was calculated. Color parameters were obtained using a spectrophotometer and were used to calculate color difference value with the preselected required color A2 tab according to Vita Classical shade guide (target shade). Color difference value (ΔE=3.7) was considered a clinically acceptable color match. Data were presented as means and standard deviation (SD) values. The independent t-test was used to compare between veneering techniques with 1mm veneer thickness.* ***Results.*** *The results showed that veneering techniques had a significant effect on mean (ΔE) values at P ≤ 0.001. The Press-on technique showed higher statistical significance difference (ΔE) Values (4.55±0.93) than layering technique (ΔE) Values (2.25±1.04) at p ≤ 0.001.* ***Conclusion.*** *The proper color matching of veneered zirconia is greatly affected by the veneering techniques. The layering technique is preferred regarding color matching.*

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INTRODUCTION

The increase in patient esthetic demands resulted in the development of number of metal-free fixed prosthesis. Zirconia based ceramics are known for their good mechanical properties and biocompatibility [1]. The opacity of zirconia is an esthetic disadvantage that hinders achieving natural and shade-matched restorations [2]. However, their optical behavior is still controversial. Initially, zirconium oxide was considered as an opaque material, due to its high refractive index and high opacity in the visible and infrared regions of the spectrum [3]. Thus, the veneering technique represents important factors affecting the color matching to natural dentition.

Zirconium Oxide is a tetragonal polycrystalline material, partially stabilized with yttrium oxide. A variety of zirconia materials exists in the market with the same chemical composition; however, they differ in their strength, color shades and translucency, based on the chosen powder type [4]. Among dental zirconia ceramic materials available nowadays is the translucent zirconia (Ice zirconia) which is used for the construction of single restorations together with long spans bridges.

This material facilitates and enables the production of aesthetical, high-quality dental prosthesis, with satisfactory results for both the patients, and the clinicians. To achieve maximum esthetics several veneering techniques has been introduced [5]. Veneering zirconia core can be done by three types of procedures: the traditional layering technique (veneered by condensing and sintering veneering porcelain), press-on technique (veneered by heat-pressing ceramic ingots), and CAD-ON technique [6].

Spectrophotometers reported to be the most accurate instruments for measuring color in dentistry. These instruments measure spectral reflectance and can express it in terms of three coordinate values (L*, a*, b*), which locate the object's color within the CIE (Commission internationale de l'éclairage) L*a*b* color space. The CIE recommended calculating color difference (ΔE) based on CIELAB color parameters [7].

However, the best zirconia veneering technique that provides optimum esthetics is yet to be evaluated. Therefore, a study is needed to assess the color matching of translucent zirconia using two different veneering techniques.

METHODS

Zirconia samples preparation

A total of twenty Zirconia (Translucent Ice zirconia zirkonzahn, Gais, Italy) disc samples were designed and constructed using zirkonzahn system computer-Aided Design/computer-Aided Manufacturing (CAD/CAM) (ZirkonzahnModellier 1.0b2 software).

The samples were classified according to the veneering technique into two groups: Group I: Ten samples (n = 10) veneered by layering technique using IPS emax Ceram dentin (IvoclarVivadent, Schaan, Liechtenstein, Canada). Group II: Ten samples (n = 10) veneered by press-on technique using IPS emax press lithium disilicate glass-ceramic (IvoclarVivadent, Schaan, Liechtenstein, Canada). Translucent Zirconia ceramic discs (12 mm in a diameter, 0.5 mm in thickness) (figure 1), were constructed from Presintered translucent zirkonzahn blocks in standardized manner using a specially designed cupper mold was machine-milled. The mold has 12 mm diameter cavity and 0.5 mm cavity depth. The cupper master mold was sprayed with scanning spray (3D anti-glare spray, Germany) recommended by Zirkonzahn manufacturer, for antireflection in order to achieve optimal accuracy. The mold was then put in its place in the Zirkonzahn scanner (S600 ARTI, Gais, Italy for 3D scanning). The Pre-sintered ceramic block of the required size was inserted in the spindle of the milling chamber of the milling machine (Roland DWX-50, Japan) and fastened with the set screw, each disc was then milled with an oversize of approximately 19.95-20.05% and shrunk subsequently to the exact final dimensions in the sintering process.

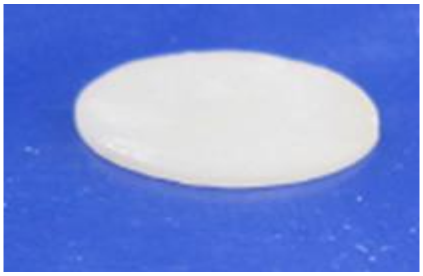

Figure 1. Zircon disk 12mm*0.5mm

After completion of the milling process and before sintering, the discs were separated from the block holder with a diamond disk (Diamond separating disc 501) at low speed of 20,000 rpm. The zirconia discs were cleaned in distilled water and grinding dust was removed before use. The Y-TZP ceramic specimens were placed in the furnace at 600 Co. The samples were rinsed by water to remove the ceramic residues, dried by compressed air. A high temperature furnace (zirkonzahnofen 600/2v, Gais, Italy) was used for the sintering of Y-TZP discs with approximately 19.95-20.05 % shrinkage. The sintering pre-program was selected, and the furnace was activated.

Veneering of zirconia core discs

Ten zirconia discs were veneered using IPS e.max Ceram dentine (IvoclarVivadent, Schaan, Liechtenstein, Canada) (shade A2) using the layering technique at thickness which was (1mm). for veneer layer application, a specially designed copper molds were machine milled in order to standardize the veneering thicknesses over the zirconia discs (figure 2). Mold consisted of two parts: an inner pistol part and an outer cupper ring. The mold was thickness & 12 mm diameter x 1.50 mm thickness.

Figure 2. Cupper mould12 mm diameter cavity and 1.5 mm thickness

A thin layer of separating medium (IPS Ceramic Separating liquid, IvoclarVivadent AG, Schaan, Liechtenstein) was applied on the walls of the molds by the aid of a painting brush. Zirconia discs were then placed inside the assembled mold. The wash firing of dentin material was brushed on the underlying zirconia substructure. This ensures controlled shrinkage of the veneering material and homogenous bond to the zirconia substructure. The IPS e.max Ceram Dentin A2 material was then mixed with the build-up liquids all round by metal spatula on a glass slab.

A thin coverage of the IPS e.max Ceram Dentin material (0.3 mm thickness) was applied on the entire veneer surface by a brush, properly vibrated with spatulation method, and dried with tissue. The samples were then positioned on the firing tray and fired according to the manufacturer firing parameters. The veneering layer was continued with IPS e.max Ceram Dentin, by the help of the copper mold with 1.5mm cavity depth, the zirconia substructure 0.5 mm thickness was seated inside the mold, and the remaining part was filled with the veneering material to create a full veneer thickness of 1 mm.

To standardize the dimensions of the veneering layer same molds used for the layering techniques were also used for the construction of wax patterns for the press-on veneer. A thin layer of separating medium (IPS Ceramic Separating liquid, IvoclarVivadent AG, Schaan, Liechtenstein) was applied on the walls of the molds by the aid of a painting brush. Zirconia discs were then placed inside the assembled mold. The press-on ivory wax (GEO brown Block-out wax - Renfert GmbH) was softened and pressed to fill the mold to form a veneering layer of (12mm diameter x 1.5mm thickness) on zirconia substructure A flat glass plate was used to cover the mold to achieve optimum smoothness of the wax pattern. After 3 minutes of hardening, the wax pattern was removed from the mold, and samples thicknesses were measured using a digital caliper (Digital Vernier caliper, Beijing, China).

Investing was carried out using IPS press VEST speed investment (IvoclarVivadent, Schaan, Liechtenstein). The IPS silicon ring (200 g) was placed over the plastic ring. Following the manufacturer instructions correct powder liquid ratio was measured and manually mixed in a plastic bowel for 20 sec. The mixing procedure was then continued under vacuum in a twister high-tech vacuum mixer unit (VPM.Whip Mix) for 2.5 minutes to provide a homogenous mix. The ring was placed on a vibrator (Emmevi, A11 dental vibrator, Zhermack) filled quickly with the mixed investment and ring gauge was positioned. After investment setting the plastic ring base and the rubber ring were carefully removed. Then ALOx plunger* was used to press the IPS e.max Press ingot during pressing procedure and the investment ring assembly were placed in the pre heating furnace (Vulcan A-130, Degussa-ney Dental, NDI Inc). The pressing procedure was activated. The ceramic ingot was then softened to be pressed into the mold under 3 bar pressure.

During the pressing program, the ceramic ingot was softened automatically while the ALOx plunger started to inject the molten ceramic into the mold which was previously occupied by wax pattern. Then the investment ring was removed from the furnace immediately after the program was completed, placed on a wide meshed grid and allowed to cool to room temperature. The samples were ultrasonically cleaned for a maximum of 10 minutes using an ultrasonic device (Ney ULTTRA sonic, USA), then thoroughly rinsed with running water and blasted with 100 µm aluminum oxide (Al_2O_3) at 1bar pressure. Samples were checked using magnifying lens at 5x magnification for detecting any defects, irregularities or cracks. Defective samples were discarded, and samples dimensions were verified by digital caliper (DigitalVernier caliper, Beijing, China).

Fabrication of composite discs

Twenty composite resin substrates in A3 shade, were fabricated according to manufacturer's instruction using a specially constructed cylindrical split Teflon mold. The mold has a circular central hole 12mm in diameter and 5mm in thickness. With an outer cupper ring that served for the assembling of the two halves of the Teflon mold. A thin layer of separating medium was applied on the Teflon mold that was seated on a clean dry glass slab. The composite material was inserted in two layers each1.5 mm, then the last 2.0-mm thick layer was applied, using a non-metallic instrument and topped with another glass slab to achieve optimum smoothness of composite resin. The resin composite was light activated for 40 seconds using a LED.D light curing unit (Miraj, LED.D curing light, Korea). After completion of curing, the top glass slab and outer copper ring were removed, the Teflon mold was opened then the samples were further light cured for another 50 seconds. The cemented side of ceramic discs was first air blasted with 50 µm aluminum oxide (Al2O3) particles at 1 bar pressure, from a distance of 10 mm for 5 seconds using an airborne-particle-abrasion device (Basic classic 25-70 µ - Renfert GmbH, Hilzigen, Germany)

The abraded discs were then washed with tap water for 1 minute ultrasonically cleaned in a water bath for 10 minutes using ultrasonic device (Ney ULTTRA sonic, USA), then air dried. The cemented side of composite discs were manually finished using wet silicon carbide paper (Norton S.A., São Paulo, Brazil) (320,600 grit) then washed with tap water for 1 minute, and ultrasonically cleaned in distilled water for 10 minutes.

Cementation of ceramic discs and composite substrate

Cementation of ceramic discs and composite substrate was done using specially designed cementation device was machined from stain less steel in order to aid in load application. The alignment device guaranteed that load applied to the sample assembly was perpendicular.

Cementation was accomplished according to the manufacture's instruction. Dual-curing translucent rely X Unicemautomix Self-Adhesive Resin luting cement was used. The excess cement was removed with a probe. The resin material was polymerized from three directions for 40 seconds with light curing device (Miraj, LED.D curing light, Korea). Finishing of each cemented disc was made using finishing bur. The thickness of each subgroup samples was measured using the digital caliper to exclude any defective one and to ensure an accurate thickness). The samples were manually polished with white silicon and grey rubber discs (Sof-Lex ™Finishing and Polishing System, 3M ESPE, Seefeld, Germany) at 20.000 rpm for 30 seconds for each sample. Procedures of finishing and polishing were done by the same technician for standardization. All disc samples (figure 3) were subjected to spectrophotometric analysis test.

Shade tab A2 (Vitapan Classical, Vita) was selected as the required target color for all fabricated restorations. In order to flatten the measuring surface of the tab, a low-speed finishing stone was used to flatten the middle portion of labial surface of the tab.

Figure 3. Disc samples after cementation

Measurement of color

A computer Color-matching system (CCM) (UV-Shimadzu3101 PC-Spectrophotometer, Japan) was used for the spectrophotometric assessment of the specimens. The Color was assessed through the measurement of the diffuse reflectance. The L*, a* and b* values of the samples were recorded according to the CIELAB color scale relative to the standard illumination D65. The color for the middle portion of the A2 shade tab was measured.

The CIE L*, a* and b*values were recorded according to the CIELAB color scale relative to the standard illumination D65.The color difference (ΔE) was calculated from the following equation $\Delta E = [(\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})]^{½}$ Where, ΔE was the color difference between A2 shade tab and the measured disc sample, ΔL* refer to difference in lightness, Δa* and Δb* refer to difference in chromaticity values between the shade tab and the measured sample.

3. Statistical analysis: Data analysis was performed in several steps. Initially, descriptive statistics for each group results. independent t-test was performed to detect significance between groups. Statistical analysis was performed using SPSS IBM V.22. P values ≤0.05 are considered to be statistically significant difference between groups.

RESULTS

Data were presented as means and standard deviation (SD) values. The independent t-test was used to compare between veneering techniques with 1mm veneer thickness. The results showed that veneering techniques (layering & press-on) and thickness (1.0 mm) had a significant effect on mean (ΔE) Values at $P \leq 0.001$. The Press-on technique showed higher statistical significance difference than layering technique where the mean (ΔE) Values were (4.55±0.93) & (2.25±1.04) respectively at $p \leq 0.001$. Mean and standard deviation (SD) of the (ΔE) Values for the two veneering techniques (layering & press-on) were presented in table (1) and (fig.4)

Table 1. Mean and SD of ΔE (Value between two the veneering techniques (layering & press-on).

Technique	Layering		Press-on		P-Value
	Mean	SD	Mean	SD	
ΔE	2.25	1.04	4.55	0.93	**≤ 0.001***

*NS= None-significant, *=Significant*

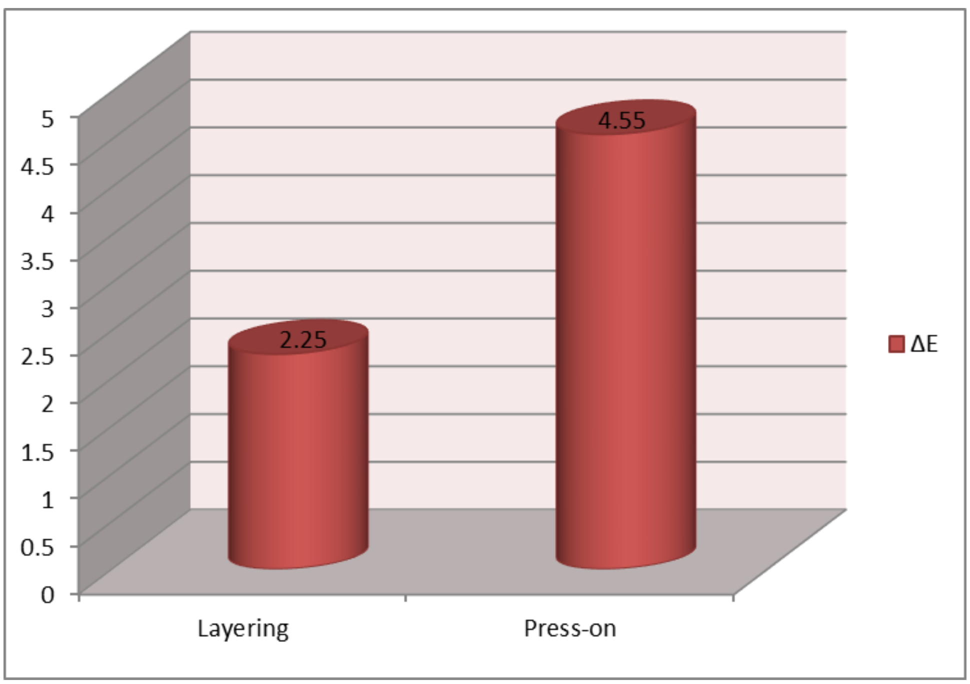

Figure 4. Histogram showing the mean (ΔE) values for the two veneering techniques (layering & press-on)

DISCUSSION

Conventional metal ceramic restorations are considered to be the standard for providing acceptable esthetics, high strength, and long-term success in the oral cavity. However, concerns about these materials regarding biocompatibility and non-optimal esthetics have been reported. Dental patients have become increasingly influenced by esthetic issues. The increase in esthetic demands, dental awareness and desire for metal free esthetic restorations have resulted in the development of a variety of all ceramic restoration systems) [8].

Yttria partially stabilized tetragonal zirconia polycrystalline (Y-TZP) showed better mechanical properties and superior resistance to fracture than other conventional dental ceramics [9]. Their high initial flexural strength (above 1000 MPa) approved by many of in vitro studies, also favored their use for the anterior and posterior regions [10].

The white color of zirconia does not allow an optimal esthetic integration to be achieved. Therefore, many alternatives were suggested to compensate for their white color. Frameworks were veneered with an appropriate veneering ceramic and more recently staining solutions for the zirconia have been used before sintering and ⁄or the use of pre-colored zirconia [11]. It was reported that the application of deep chroma dentin over the colored zirconia was necessary to reproduce the required color [12].

In the present study, shaded zirconia substructure was used, due to its good esthetic results, and thus allowing a more natural appearance similar to the opaque, yellow dentine overlaid by translucent enamel [13].

The layering technique represents the most common technique for veneering zirconia restorations sintered onto ceramic cores. Recently, a heat pressing technique has become also available for veneering the all-ceramic restorations. The layering technique is thought to be a sensitive veneering technique because of the brush applied build-up and frequent firing steps [14]. The press-on technique is preferred due to its accuracy. In addition, framework supported wax patterns can be tried in the mouth enabling adjustments before pressing and sintering without influencing their mechanical properties. However, its optical qualities remain questionable [9]. Thus the present study aimed to evaluate the effect of different veneering techniques (layering & press-on) with (1 mm) veneer thickness on color matching of translucent ice zirconia substructure.

The color and its parameters, such as hue, value, chroma, translucency, opacity, and fluorescence, influence the final esthetic of a dental restoration. Also, another environmental factors like the metamerism and the light scattering can affect the esthetic appearance of fixed prosthesis [15]. Color reproduction is one of the most challenging arts in esthetic dentistry and is significantly influenced by the methods used to evaluate, transfer, and imitate the color. These challenges become even more obvious when there is a need to investigate the exact role of different variables on the overall appearance of all-ceramic restorations to produce guidelines for both clinicians and ceramists [12].

The different veneering materials, techniques, and all contribute to perceptible differences between the resultant shade of dental porcelains and their respective shade tabs [16,17]. IPS e.max Ceram used in the layering technique is characterized by a high stability of shape and shade, even after several firing cycles, and this permits a unique combination of translucency, brightness and opalescence [6].

In the present study the mixing ratio of the IPS e.max Ceram powder and build-up liquids was done following the manufacturer recommendations to control the firing shrinkage of the ceramic mass which was applied by the same technician to exclude any errors. All samples were fired in the same furnace together with the same number of firing cycles. Based on the shade combination table recommended by the manufacturer to produce restoration of shade A2; IPS e.max Ceram A2 was used in case of layering technique while IPS e.max Press LT A2 was selected for the press-on technique, and compared with the shade tab A2 Vita Classical shade guide (target color) for all fabricated samples [18].

Specially designed molds were used to standardize the veneer construction. The molds had inner pistol part to facilitate removal of the discs after veneer application or wax pattern construction and an outer cupper ring to stabilize the assembled parts. In the present study, the thickness of translucent zirconia substructure was 0.5 mm in order to minimize the effect of edge loss, which is the least recommended thickness for fixed restorations [19,5]. Since the veneer thickness may vary depending on the available occlusal space and the anatomic characterization level of the restoration. The porcelain thicknesses used in the present study were 1 mm in thickness as recommended by the manufacturer, while 1 mm is the typical thickness used in dental practice [20].

Composite resin discs A3 in shade were fabricated to simulate dentin [21]. For standardization a specially constructed cylindrical split Teflon mold was constructed. The Teflon mold has a circular central hole 12 mm in diameter and 5mm in thickness. An outer cupper ring served to assemble the two halves of the Teflon mold.

In this study, translucent self-adhesive rely X Unicem cement was selected to bond the ceramic disc with the composite substrate, and to exclude its effect on color measurement. In the present investigation, a special loading device was constructed to insure a constant 2 kg load to simulate the finger pressure and to bond the samples without any eccentric movements.

Finishing and polishing for the veneering surface of all specimens was done with white silicon and grey rubber discs at 20.000 rpm for 30 seconds, applied by the same technician for standardization. A flat surface was achieved after the finishing procedure, required for the measurement of the color parameters, to allow the contact tip of the spectrophotometer to contact the surface without any angulations [22]. White silicone and grey rubber discs were also used to flatten and finish the middle portion of the labial surface of the Vita Pan classical shade tab A2 to allow more consistent color measurement (less coefficient of variation), as the translucency of the incisal edge and the cervical site may affect the color measurement. The metallic hand was also removed after polishing so as not to affect the color measurements [23].

Veneering porcelains are more translucent than zirconia. Thus, a background might express its color under the zirconia coping, affecting the resultant color of a zirconia-based ceramic. The resultant color is the outcome of the ceramic and background colors [24]. Natural colors such as white, grey and black are by definition, colors that have no hue. The white background was selected as a background to minimize the influence of background hue on the color measurement of the discs [19]. This arrangement allowed the investigation to focus on the effect of the veneer thickness on the disk color appearance.

Accurate and reliable evaluation of color is a prerequisite for a successful esthetic result. Spectrophotometers measures the amount of light energy reflected from an object at 1-25 nm intervals along the visible spectrum) [25]. These devices have the ability to detect and quantify minor color differences as their limit of detection during in vitro quantification of monochromatic samples is considered to be 0.1 ΔE units [26]. In the present study, Spectrophotometer was used for color analysis. It was stated that Spectrophotometers offered a 47% increase in accuracy and a more objective match in 93.3% of cases [27].

The Commission Internationale de l'Eclairage (CIE) L*a*b* color system is widely used to evaluate differences in color between dental restorations and teeth because of its validity, feasibility, and simplicity. The CIEL*a*b* system evaluates the degree of perceptible color change based on 3 parameters: L* (lightness, in which 100 represents white and 0 represents black), a* (red–green chromatic coordinate) and b* (blue–yellow chromatic coordinate). For the evaluation of color match, the color difference value (ΔE) is usually used and it represents the numerical distance between L*a*b*[28].

Several studies tried to report acceptable ΔE limit but variations among these studies were noticed. (Seghi et al., 1986), reported a color difference of ΔE = 2, on same way, [29] (Ragain et al 2001). stated that the average CIE L*a*b* color difference for a match in the oral environment was (ΔE =3.7) [30]. Finally (Khashayar et al in 2014) explained in his review that more than half of the studies defined perceptibility thresholds as ΔE = 1, and acceptability threshold as ΔE = 3.7 being the threshold at which 50% of observers accepted the color difference [31]. The value reported in Khashayar study has been referenced for many years and so it was the reference for the present study.

The results of the present study reported that a statistical significance difference was found between the layering technique and press-on technique, where the mean (ΔE) values of press-on technique was (ΔE = 4.55), which is considered above the perceptible value compared to the layering technique where the mean (ΔE) values was (ΔE = 2.25).

These findings were in agreement with (Zhang et al 2008) [32], who stated that the color of zirconia all-ceramic restoration veneered with the layering technique tend to be similar to standard shade tab and that the color difference was minimum, while the press-on technique showed the maximum color difference (ΔE= 4.86).

the result of the present investigation could be explained by the fact that the ingots for heat-pressing and the IPS ceram for layering are different in the infrastructure, homogeneity, porous, volume and in the pigment contents. Therefor the differences in the L*a*b* values were detected (Kim et al 2014; Luo & Zhang 2010) [8,5].

Also, these results were in agreement with Mahrouse, A et al 2014 [23], who found that the layering technique is the best concerning the color matching while the press-on technique was the worst. The press-on technique showed (ΔE =4.23) which is considered above the perceptible value followed by double veneer (ΔE = 3.83) and layering techniques (ΔE = 3.73) which was within the perceptible value with no statistical significant difference.

On the other hand, our results were in contrast to those of Ugur M & Kavut I 2021[33], who reported No complete color match has been achieved between the color scale proposed by the manufacturer companies and the zirconia-based full ceramic system. The technique that shows the most color incompatibility with the color scale was the layering technique, while the technique with the best color match is the pressing technique.

CONCLUSIONS

This study concluded that proper color matching of veneered zirconia is greatly affected by the veneering techniques. In this study the Press-on technique showed higher statistical significance color difference than layering technique. Therefor from an esthetic point of view the layering veneering technique is preferred.

Disclaimer

The article has not been previously presented or published, and is not part of a thesis project.

Conflict of Interest

There are no financial, personal, or professional conflicts of interest to declare.

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