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EFFECT OF DIFFERENT SURFACE TREATMENTS ON COLOR STABILITY OF ULTRA-TRANSLUCENT ZIRCONIA OCCLUSAL VENEERS BEFORE AND AFTER THERMOCYCLING AGING

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ABSTRACT

Aim: The purpose of this in vitro study was to evaluate the effects of three different surface treatment protocols on the color stability of ultra-translucent zirconia occlusal veneers before and after thermal cycle aging.

Materials and methods: Twenty-eight maxillary first premolar teeth were selected. Each tooth was embedded in an acrylic resin block, and minimally occlusal veneer preparation was made with a 1mm reduction. All prepared teeth were scanned using the Cerec scanner. The veneer restorations were designed and milled. The teeth samples were randomly divided into four groups (n = 7) according to the type of surface treatment performed on the intaglio surface of the ultra-translucent zirconia occlusal veneer restoration; group I: No surface treatment (Control), group II: Air-particle borne abrasion, group III: Er, Cr: YSGG laser, group IV: Ceramic primer (MDP) application. The restorations were cemented using a dual-curing resin cement. The veneer samples' color of all groups was measured using a spectrophotometer according to the CIE L*a*b* color before and after 5000 thermal cycles. Then, the color difference (ΔE) for the surface treated specimens before and after aging was measured. The data was investigated statistically with a significance value of $p < 0.05$.

Results: Significant differences in the mean color change (ΔE) values were observed between all tested surface treated groups (p value <0.001). Before aging, the veneers with air abrasion showed the highest color change (2.89±0.24) followed by the laser group (2.07±0.36). The MDP primer group showed the least color change (0.75±0.09). Also, after aging, air abrasion treatment group showed the highest change in color (3.06±0.23) followed by the laser group (2.31±0.29). While MDP primer group showed the least color change (0.85±0.11). There was no statistical difference between each group before and after thermocycling (p value >0.05).

Conclusions: Air-borne particle abrasion had the highest significant effect on the color change of ultra-translucent zirconia occlusal veneer compared with MDP primer and laser treatment. Surface treatment had resulted in color change of ultra-translucent zirconia occlusal veneer, but it was clinically acceptable even after aging. Thermocycle aging did not significantly affect the color change of ultra-translucent zirconia.

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INTRODUCTION

The loss of the occlusal tooth structure surface may occur over time due to erosion or wear, which could expose the underlying dentine [1]. To compensate for this damage, a prosthetic restoration may be required. With the improvement of ceramic materials and bonding techniques, minimally invasive restorations such as occlusal veneers are considered[2]. Occlusal veneer is a completely adhesive retained restoration of the occlusal surface of worn-down dentition to provide a proper esthetic and masticatory function [3].

The suitable ceramic materials for this type of minimally invasive restoration are lithium disilicate glass-ceramics and zirconia [4]. The CAD CAM lithium disilicate glass-ceramics can be milled into thin sections. Being silica-based ceramics, they have a high bonding ability to resin cements through conditioning with hydrofluoric acid followed by silanization.

Ttranslucent zirconia is considered an esthetic monolithic material with a high fracture resistance [5]. These properties enable the material to be used in minimally invasive restorations, as an occlusal veneer restoration [3,4]. However, the high translucent zirconia is considered a polycrystalline structure that is chemically inert and non-etchable with hydrofluoric acid, which makes its adhesion to the tooth structure problematic compared with silica-based ceramics. Therefore, using this monolithic zirconia veneer, relying completely on adhesion to tooth structure, is considered a challenge [6]. A strong bond between translucent zirconia and resin cement is absolutely required. So, the inner surface of the restoration should be surface treated for mechanical and chemical bonding [7].

Several surface treatments have been proposed, including airborne particle abrasion, tribochemical silica coating, and laser irradiation [8]. Sandblasting using aluminum oxide particles at high air pressure creates a rough surface for mechanical retention and increases the surface area for bonding [9]. Tribochemical silica coating also, creates a rough surface, and the inserted silica and alumina particles react chemically with the silane coupling agent [10]. Er: YAG lasers with suitable parameters have been recommended to improve the micromechanical retention through modifying the intaglio surface of zirconia [11]. Ceramic primers containing 10-methacryloyloxydecyl dihydrogenphosphate (MDP) have been introduced to increase chemical bonding to zirconia ceramics, as they are able to bond with zirconium oxide and metal oxides [12].

Optical features like color stability and translucency should be taken into consideration in the selection of ceramic restorative materials to maintain esthetics [13]. These optical characteristics might be affected by the material surface treatments required for bonding as well as aging [14]. Furthermore, the color of the translucent ceramic restoration can be influenced by its thickness, the cement shade, and the underlying dentin [15, 16].

An objective measurement of color and translucency of dental materials can be done by certain instruments called spectrophotometers [17]. Spectrophotometers evaluate the color according to the CIE Lab color scale relative to the Commission Internationale de l'Eclairage (International Commission on Illumination). This system defines color in terms of three coordinate values (L*, a*, and b*), which locate the color of material within a 3D color space. The L* represents the brightness of an object, the a* represents the red/green chroma, and the b* represents the yellow/blue chroma [18]. The color difference (ΔE) of two measurements of the same object can be determined by comparing the differences between the respective coordinate values of each measurement through certain equations.

Previous studies investigated the effects of varying resin cement colors and material thicknesses on the color and translucency of a high-translucency monolithic zirconia[16]. However, information

regarding the effect of surface treatment before and after the aging of this material is lacking. So, the purpose of this in vitro study was to evaluate the effects of three different surface treatment protocols on the color stability of ultra-translucent zirconia occlusal veneers before and after aging.

MATERIALS AND METHODS

The type of zirconia used for fabrication of occlusal veneers in the study was ultra-translucent zirconia (BruxZir anterior, Glidewell, California, USA), table 1.

TABLE (1): The ultra-translucent zirconia and its composition used in the study

Material	Manufacturer	Composition
Ultra-translucent zirconia	BruxZir anterior, Glidewell, California, USA	zirconium oxide >97.5% wt, yttrium oxide 7.5% wt, hafnium oxide <2% wt, aluminum oxide <0.5% wt, silicon oxide <0.02% wt, Iron oxide <0.01% wt, sodium oxide <0.04% wt.

Twenty-eight recently extracted human maxillary first premolar teeth, with approximate bucco-lingual and mesio-distal dimensions, were selected for this study. The teeth were free from cracks, caries, or restorations. Any calculus or soft tissue debris was removed from the teeth and then cleaned with a rubber cup and fine pumice-water slurry. All teeth were disinfected with 5% sodium hypochlorite and stored in distilled water at room temperature. Each tooth was embedded in a cylindrical Teflon mould filled with an auto polymerizing acrylic resin (Acrostone dental factory, Industrial zone, Cairo, Egypt) to a level two mm below the cemento-enamel junction. The teeth were mounted with their occlusal surfaces perpendicular to the long axis of the resin block.

The teeth samples were randomly divided into four groups (n = 7) according to the type of surface treatment performed on the intaglio surface of the translucent zirconia occlusal veneer restoration; group I: No surface treatment (Control), group II: Air- borne particle abrasion, group III: Erbium, chromium:yattrium-scandium-gallium-garnet laser (Er, Cr: YSGG laser) surface treatment, group IV: Ceramic primer (MDP) application.

Tooth preparation:

A minimally occlusal veneer preparation was made for each tooth, simulating the occlusal surface of a worn premolar. All teeth preparations were done by the same operator using a high-speed contra angle handpiece and a copious amount of water spray. One mm of the occlusal surface was reduced [19] (figure 1; a, b). The preparation was started by using a 0.8 cylindrical diameter diamond bur to make 4 depth grooves following the inclined planes of the occlusal surface. Then, these grooves were connected by removing the enamel islands in between using round-ended tapered diamond burs. To check the uniformity of tooth reduction, two silicone indexes (3M ESPE, Imprint II, Germany) were made at the buccal–lingual and mesial–distal directions [19].

Occlusal veneers fabrication:

CEREC AC Omnicam intraoral scanner (Dentsply Sirona GmbH, Bensheim, Germany) was used to scan all the prepared maxillary premolars. The design of occlusal veneers was performed using CEREC SW software (version 4.5, Sirona Dental Systems GmbH, Bensheim, Germany) (figure 1;c,d). A standardized restoration design with similar occlusal surface anatomy and a uniform thickness of 1 mm was saved and sent to the milling machine. All restorations were milled with the 5-axis dry milling machine MCX5 (Dentsply Sirona, Bensheim, Germany). Milling of a zirconia blank (BruxZir anterior, Glidewell, California, USA) was performed to produce the restorations 20% larger in size to compensate for

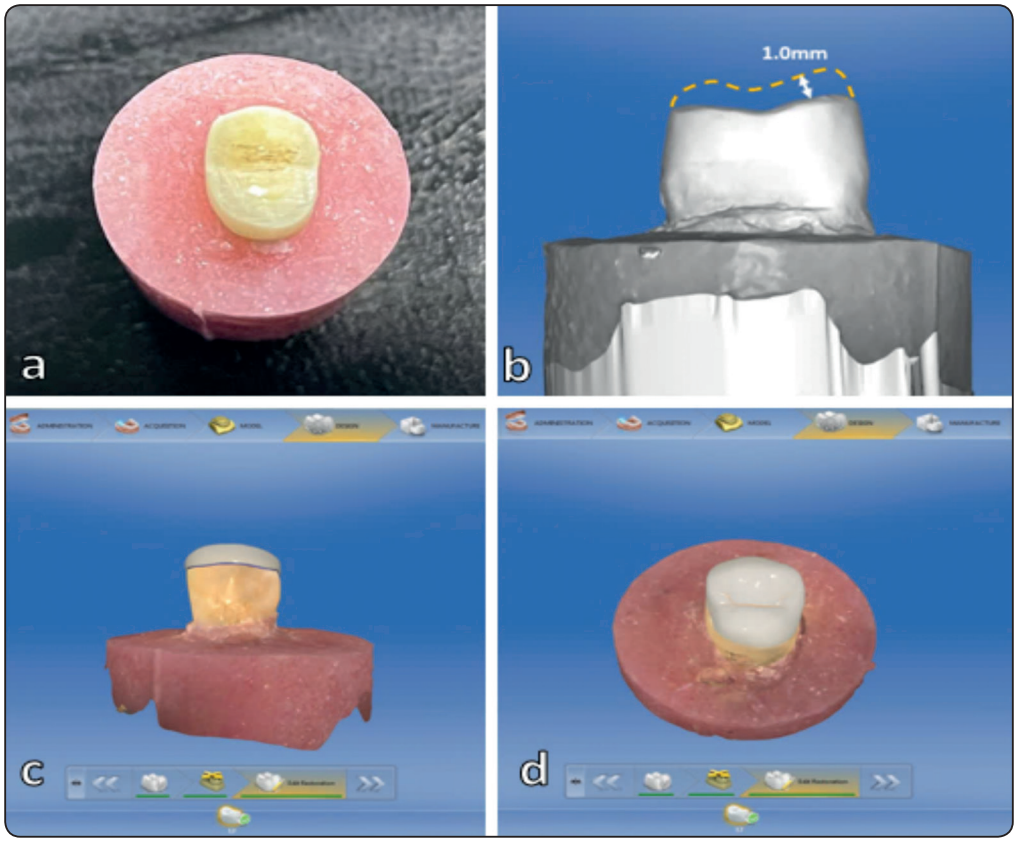

Fig. (1): Specimen of occlusal veneer; a) Prepared Maxillary premolar, b) Reduction of the occlusal surface to 1.0mm, c) Virtual design of occlusal veneer restoration (Buccal view), d) Occlusal view.

shrinkage after sintering. The zirconia veneers were placed in a special sintering furnace (nabertherm, Lilienthal, Germany) and sintered according to the manufacturers' instructions. All veneers were ultrasonically cleaned in distilled water for 10 minutes, and air dried. Then, it was polished with diamond polishers.

Surface treatment:

For group I, seven occlusal veneers were left untreated, and it is considered the control group. The specimens were cleaned with 70% ethanol and cemented to their respective prepared teeth. For group II, the inner surfaces of seven occlusal veneers were sandblasted using aluminum oxide particles of 50 µm size at an angle of 90, an 8 mm distance for 30 seconds, and 2.5 bar pressure. The veneers were then cleaned in an ultrasonic cleaner for 3 minutes and dried.

Laser surface treatment was made to the fitting surface of seven veneers of group III. The samples were irradiated with an Er, Cr, YSGG laser using Waterlase Iplus (Biolase, California, USA). The device was adjusted to a power of 4 watts, wavelength of 2780 nanometers, and frequency of 50 HZ, with 80% water and 60% air. The hard mode was selected, and each veneer was irradiated for 1 minute at a distance of 3 mm.

For group IV, the inner surfaces of the last seven samples were treated with a ceramic primer (iTENA C-RAM BOOSTER, France). The primer was applied onto the intaglio zirconia veneer surfaces for 30 seconds using a disposable brush and left for approximately 30 seconds to dry.

Cementation of veneers

The enamel and the dentin of all prepared teeth specimens were etched with 37% phosphoric acid gel (Ivoclar Vivadent AG, Liechtenstein) for 30 s. The surface was rinsed with water spray and air-dried. A bonding agent (ADHESE Universal, Ivoclar Vivadent AG, Liechtenstein) was applied to the tooth surface and to the veneer restorations, air thinned. The restorations were cemented using the transparent shade of a dual-curing resin cement (Multilink Automix; Ivoclar Vivadent). Excess cement was removed. A constant load was applied vertically to each of the cemented samples, and they were light cured for 40 seconds. All samples were immersed in distilled water and stored at room temperature till testing.

Thermocycling

Aging for all samples was done by thermocycling. Using a thermal cycle machine (Robota automated thermal cycle; BILEGE, Turkey), all specimens were subjected to 5000 thermal cycles (equivalent to 6 months of clinical condition) [20]. The immersion time was 25 seconds in each water bath.

Color measurements

Color measurements were taken for all samples before and after thermocycling. The occlusal veneer samples' color was measured using a reflective spectrophotometer (CM-700d, Konica Minolta Sensing Inc., Tokyo, Japan) according to the CIE L*a*b* color scale relative to the Commission Internationale de l'Eclairage CIE standard illuminant D65 [21]. Calibration of the spectrophotometer was performed before measurement of each specimen. The flat surface of the spectrometer's pointer was positioned against the center of the ceramic occlusal veneer, and a white background was selected as it is considered more suitable for posterior teeth [22].

The color difference (ΔE) of two measurements in the same object, before and after exposure to certain conditions like surface treatment or aging, can be determined by the differences between the respective coordinate values of each measurement through the following formulas:

$$\Delta E = [(L_1 - L_2)^2 + (a_1 - a_2)^2 + (b_1 - b_2)^2]\ ½$$

$$\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]\ ½$$

Where: L* = Change in lightness (0-100), a* = change the color of the axis (red/green) and b* = color variation axis (yellow/blue).

Statistical analysis

Analysis of data were performed using Statistical package for Social Science (SPSS) version 22.0. Quantitative data were expressed as mean ± standard deviation (SD). Qualitative data were expressed as frequency and percentage. one-way ANOVA was used to test the difference between the ΔE mean values of several groups of a variable. Post-hoc test was used for comparison of groups when the ANOVA test is positive. The confidence interval was set at 95%. P-value <0.05 was considered statistically significant.

RESULTS

The surface treated groups were compared as regard to the change in color (ΔE) before and after thermocycling. For each group, the mean and standard deviations of the change in color (ΔE) are presented in table (2) and graphically drawn in figure (2). The one-way ANOVA test showed that there was statistically significant difference in the mean color change (ΔE) values between all tested surface treated groups (p value <0.001).

Before aging, the surface treated veneers with air abrasion showed the highest color change (2.89±0.24) followed by laser group (2.07±0.36). MDP primer group showed the least color change (0.75±0.09). Also, after aging, air abrasion treatment group showed the highest change in color (3.06±0.23) then laser group (2.31±0.29). While MDP primer group showed the least color change (0.85±0.11).

TABLE (2): Mean and standard deviations of the tested surface treated groups as regard to the color change (ΔE) of before and after thermocycling

Groups	Air abrasion (n=7)	Laser (n=7)	MDP primer (n=7)	F	P-value
ΔE Before aging	2.89±0.24	2.07±0.36 ¥	0.75±0.09 €₱	127.45	<0.001
ΔE After aging	3.06±0.23	2.31±0.29 ¥	0.85±0.11€₱	175.45	<0.001
t	1.3	1.4	1.9		
p-value	0.21	0.18	0.08		

Data expressed as mean ± SD, F= one way ANOVA, t=student t test, ¥ = post hoc Tukey test significant between Laser group and Air abrasion group, € = post hoc Tukey test significant between MDP primer group and air abrasion group, ₱ = post hoc Tukey test significant between MDP primer group and Laser group.

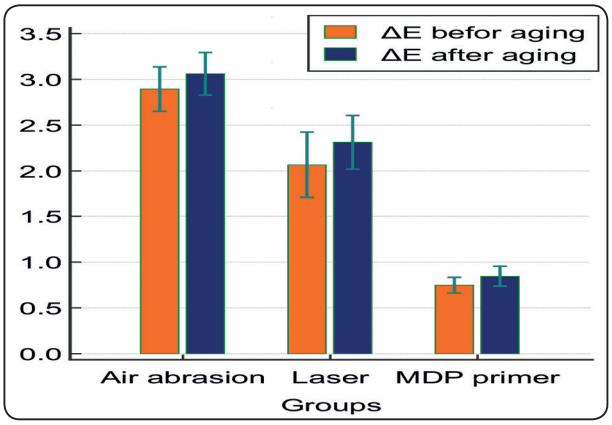

Fig. (2): Bar chart showing mean values of color change (ΔE) for surface treated veneer groups before and after thermocyclic aging

Each group was compared as regard color change (ΔE) before and after aging. and there was no statistical difference between them (p value >0.05).

DISCUSSION

Ultra-translucent zirconia is a highly esthetic material with optimal mechanical properties. Because of these good properties and conservative tooth preparation, monolithic translucent zirconia ceramic is frequently used in restorative dentistry. It can be used in minimally invasive restorations that necessitate less tooth reduction and material thickness without compromising its strength.

Regardless of the microstructure of zirconia, the adhesive luting protocol necessitates surface treatment of the restoration's intaglio surface, which has been reported to improve the bond strength of the restorative material to resin cement [23]. The aim of this study was to evaluate the influence of surface treatments on the color stability of ultra-translucent zirconia before and after thermocycle aging.

In this study, occlusal veneers of the first group were left untreated as the baseline color was measured to evaluate the color difference **ΔE** with the other three surface treated groups. Color was measured in this study using a spectrophotometer device, which can express the outcomes in terms of color coordinates and yet is the most suitable and accurate tool for dental color measurements [24].

The results showed significant differences in **ΔE** values between the three-surface treated veneers; air abrasion, MDP primer, and laser treatment either before or after aging (P <0.05). The greatest color change occurred after air-borne particle abrasion.

It has been reported that airborne particle abrasion with 50-110m alumina particles is effective in roughening and modifying the surface topography of zirconia [25]. Kim and Ahn [26] explained that sandblasting's impact process gives alumina particles a lot of kinetic energy and heat, which causes local surface melting on the zirconia surface and

microcracks. Regardless, these changes have a favorable effect on the bonding of resin cement to ceramic, but they may also have resulted in alterations in the optical properties of the zirconia veneers[23,27]. Furthermore, airborne particle abrasion increased the surface roughness of ultra-translucent zirconia ceramic more effectively than the other surface treatment methods. It is apparent that due to the increased roughening of the zirconia surface, the light that passes through the restoration is more scattered in incidence and direction [23].

Er,Cr:YSGG laser irradiation is progressively utilized in dentistry as a means for the removal of caries, cutting soft and hard tissues, and surface treatment of teeth and ceramics [11, 28]. It can be used as another alternative surface treatment to improve the bond strength between restorative materials and resin cements. Kara [29] reported that surface treatment of zirconia ceramics improved bond strength using Er,Cr: YSGG lasers. Er,Cr:YSGG laser modifies the ceramic surface through the production of micro ablations, which causes surface heat vaporization and results in surface irregularities [30]. However, the energy level used for Er,Cr:YSGG was high (4w), which might result in more surface irregularities but decrease the strength of the restoration [31].

In this study, color change was found in the laser treatment group. The result was in agreement with Kurtulmus-Yilmaz et al [31] who reported that the capacity of the laser to remove surface particles by micro-explosions and vaporization, a process known as ablation, caused the color change. The effect of the Er; Cr; YSGG laser on the color change of ceramics was also confirmed by Vohra et al [32] in their in vitro study.

MDP primer has been utilized to alter the surface of zirconia in order to improve the reactivity of zirconia, thus enhancing its bond strength to resin cement. The MDP monomer contains a phosphate ester group and a methacrylate group, which promotes a chemical bond to oxide ceramics that is long-lasting clinically [33].

In this study, MDP primer, being an adhesive, it also altered the color of the translucent zirconia occlusal veneer, but significantly less than sandblasting and laser treatment. Oliveira Jr et al [34] examined the effect of different adhesives on the color stability of ceramic veneers and reported that adhesive systems had a significant effect on color change. They explained that it may be due to the increased number of solvents incorporated in these adhesives, which are subjected to degradation and color change with time. Moreover, the primers formed carboxylate and phosphate salts on the zirconia surface to allow adhesion [35]. These salts may function as scattering centers, altering the pattern of light transmission, and hence changing zirconia's optical characteristics.

Color was also measured for the three surface treated groups after aging and the color change **ΔE** from the non-surface treated (control) group was estimated. The results of this study indicated that aging by thermocycling caused a non-significant color change for each surface treated group. The ultra-translucent zirconia used in this study contains more than 6mol% yttria, which increases the cubic phase content. This cubic phase improves the restoration's translucency and inhibits hydrothermal degradation in vitro and in the absence of load [36]. The lack of hydrothermal degradation is responsible for color stability of ultra-translucent zirconia veneers. However, the current study's non-significant color change after thermocycling could be attributed to the minimal veneer thickness of 1 mm, which enabled observation of the luting cement's color change. The result agreed with Ashy et al [37] who studied the in vitro effect of thermocyclic aging on the color stability of high translucency monolithic lithium disilicate and zirconia ceramics luted with different resin cements.

When a color change in the restoration can be recognized by the human eye, it is said to be perceptible, and acceptable when it is tolerated [38]. In their review study, Khashayar et al [39] used $\Delta E = 1$ as the perceptibility threshold for color difference

and ΔE = 3.7 as the acceptability threshold. The color change either before or after thermocycling is regarded as perceptible for both air-borne particle abrasion and laser surface treated groups but clinically acceptable for all surface treated groups.

Because it has no significant effect on the color change of the zirconia occlusal veneers, the MDP primer approach looks to be the preferred surface treatment method in the study. Clinicians should exercise greater caution when using airborne particle abrasion or laser treatments, taking into account the effect on the colour difference of veneer restorations. More investigations will be needed to evaluate the effects of different shades, polymerization modes of resin cements, and the effect of underlying tooth color on the color difference of translucent zirconia restorations.

CONCLUSIONS

Within the limitations of this study, it can be concluded that:

- Air-borne particle abrasion surface treatment had the most significant effect on color change of ultra-translucent zirconia compared with MDP primer and laser treatment.
- Surface treatment had resulted in color change of ultra-translucent zirconia occlusal veneer, but it was clinically acceptable even after aging.
- Thermocycle aging did not significantly affect the color change of ultra-translucent zirconia occlusal veneer.

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