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Effect of Aging Process on Color Stability and Shear Bond Strength of Veneered Zirconia Ceramics; (In-vitro Study)

Abd El-Aziz H. A. Mahmoud, Mohamed F. Mewally** and Khaled M. Haggag****

ABSTRACT

Purpose: To evaluate the effect of artificial accelerated aging on color stability and shear bond strength of veneered zirconia ceramics. Materials and methods: A total of 60 zirconia samples were used in this study. Samples were made of CAD/CAM substructure (in Coris ZI) and hand layered with porcelain VM9 & Crea.Lign composite veneering material. Samples were divided into two main groups, color group (20 samples) and shear bond strength group (40 samples). Color group was subdivided into two subgroups according to veneering material used, (subgroup I) for porcelain veneered zirconia (10 samples) and (subgroup II) for composite veneered zirconia (10 samples). Shear bond strength group was also subdivided into two subgroups according to veneering material used, (subgroup I) for porcelain veneered zirconia (20 samples) and (subgroup II) for composite veneered zirconia (20 samples). Initial color measurements using Spectrophotometer and shear bond strength measurements using a universal testing machine were carried out. Samples were subjected to hydrothermal aging for 5 hours. Another color and shear bond strength measurements were again carried out after artificial aging of the samples. Data was statistically analyzed using Student t-test, Paired t-test and the significance level was set at $P \leq 0.05$ Results: All samples showed a statistical significant difference in color stability and shear bond strength before and after hydrothermal aging ($P > 0.05$). Conclusion: Shear bond strength and color stability of veneered zirconia ceramics were significantly decreased

* Demonstrator of Crown & Bridge department, Faculty of Dental Medicine (Cairo, Boys), Al Azhar University.

** Lecturer of Crown & Bridge department, Faculty of Dental Medicine (Cairo, Boys), Al Azhar University.

*** Professor of Crown & Bridge department, Faculty of Dental Medicine (Cairo, Boys), Al Azhar University.

by artificial accelerated aging.

Keywords: Zirconia, porcelain VM9, Crea.Lign composite, Color stability, Shear bond strength, Aging

INTRODUCTION

Ceramics are widely used as restorative materials due to their favorable properties such as strength, biocompatibility and esthetics (1). Yttria partially stabilized tetragonal zirconia (Y-TZP) is one of the most used ceramic in dentistry for fabricating substructures due to its favorable mechanical and optical properties (2). Although the metal ceramic restorations are the gold standard option for fixed dental prosthesis, ceramic restorations with zirconia substructure have been preferred especially in esthetic zone (3, 4). The whitish color and the relatively low translucency do not allow zirconia to be used alone to solve all esthetic situations; therefore, in many clinical situations, a more esthetic veneering material, like a glass-ceramic, needs to be applied over the zirconia framework in order to achieve an acceptable esthetic results (5).

Monolithic zirconia FDPs has been recently used in different situations anteriorly & posteriorly to prevent porcelain chipping but long term clinical performance or success of this material has not been extensively studied [6, 7]. Bi-layered zirconia consist of a high strength zirconia substructure veneered with ceramic material such as feldspathic porcelain. Although the resultant restorations have excellent esthetic properties, they are prone to failure such as chipping or delamination of the veneering ceramic [7, 8].

A possible solution for repairing a fractured ceramic veneer is to bond composite resin intra-orally, but this is considered a compromised solution due to strength reduction, bond failure and potential color mismatch of the material over time [9]. An alternative may be to consider veneering with composite, which may have the advantage of absorbing occlusal stresses especially with implant supported FDP [10]. Composite resins are widely used due to their excellent physical, optical and mechanical properties [11].

Artificial accelerated aging is a method that simulates the clinical conditions to which materials are subjected. Hydrothermal aging of zirconia may have detrimental effects on its bonding with veneering ceramics, mechanical stresses, temperature alteration and wetness exposure accelerate this process [12, 13].

Color match and stability are critical determining factors for both initial and the long-term esthetic success of a dental restoration. [14, 15].

It will be of interest to study the possible effects of aging process on color stability and shear bond strength of veneered zirconia ceramics.

Therefore; the null hypothesis of this study was that; artificial accelerated aging had no effect on color stability and shear bond strength of veneered zirconia ceramics.

MATERIALS AND METHODS

Preparation of zirconia samples:

Micro saw (Isomet 4000 micro saw,Buehler, USA) was used to obtain 60 zirconia samples. 40 rectangular samples for shear bond strength test with final dimensions 2 mm thickness, 14 mm length and 12 mm width. 20 square samples for color stability test with final dimensions 1 mm thickness, 10 mm length and 10 mm width. The final thickness of the discs was verified with a digital caliber (0.002 accuracy). The samples were then sintered in (infireHTC, Sirona) in

1505 °C for 7 hours and then cleaned in an ultrasonic cleaning bath in 70% ethanol for 15 minutes. Samples were sandblasted with 110 μm particle size Al_2O_3 for zirconia composite group, and 50 μm particle size Al_2O_3 for zirconia porcelain group while the discs were held facing the nozzle of the sandblasting machine using customized device to standardize the distance between the nozzle and the surface of the zirconia sample to 10 mm. Pressure was adjusted to 0.2 MPa for 20 seconds.

Mold fabrication for shear bond strength samples:

A specially designed splitted circular shaped brass metal mold with 3 mm height and 5 mm internal diameter was fabricated. It was surrounded by outer plastic ring to stabilize and hold the two halves of splitted mold.

Mold fabrication for color stability samples:

Another specially designed splitted square shaped brass metal mold was fabricated with 2 mm height (1 mm for zirconia substructure & 1 mm for veneering materials) and 10 mm width and length . It was also surrounded by outer plastic ring to stabilize and hold the two halves of splitted mold.

Veneering with Composite:

- **Color stability samples:**

A clean brush was used to apply the MKZ primer to the conditioned surface of zirconia disc which was positioned in the assembled mold then left 30 seconds for drying.

A clean brush was used to apply a thin layer of crea.lign opaker on the surface of the disc and polymerized for 180 sec in Bre. Lux Power Unit2 curing device. A thin layer of Crea.Lign dentine paste A3 was applied over the opaker and polymerized for 180 sec. The sample was disassembled from the mold with caution, dentine layer was corrected and checked for a final thickness of 0.5 mm using digital caliber. Crea.Lign enamel gel A3 was applied over dentine to full fill the remaining space in the mold. The final dimensions were obtained (1 mm final thickness of zirconia veneered with 1 mm final thickness of composite). Finishing and polishing of the samples were done by bredent composite veneer finishing kit and material to achieve perfect high shine polished veneers.

- **Shear bond strength samples:**

MKZ Primer and opaker were applied over the square color stability samples as done before in color stability samples. A thin layer of crea.lign dentine paste A3 (2mm maximum layer thickness) was applied over the opaker and polymerized for 180 sec. The sample was disassembled from the mold with caution. The final thickness was obtained (2 mm thickness of zirconia + 3 mm thickness & 5 mm diameter of the veneer).

Veneering with porcelain:

- **Color stability samples:**

Dentin VM9 was packed over zirconia samples which was positioned in the assembled mold. The sample was disassembled from the mold with caution and fired in Vacumat 40 T oven. After firing the dentine layer was checked for a final thickness of 0.5 mm using digital caliber. Enamel VM9 was packed over the dentine layer to full fill the remaining space in the mold. The sample was disassembled from the mold with caution and fired. The final dimensions were obtained (1 mm thickness zirconia veneered with 1 mm thickness veneering porcelain).A glaze layer was applied to obtain a smooth surface ready for color stability test.

- **Shear bond strength samples:**

Dentin VM9 was packed over zirconia samples which was positioned in the assembled mold. The sample was disassembled from the mold with caution and fired in Vacumat 40 T oven. The final dimensions of the veneering porcelain were obtained (3mm thick& 5mm diameter).

Shear bond strength evaluation:

Samples were mounted on a computer controlled Universal testing machine (Model 3345; Instron Industrial Products, Norwood, USA) with a load cell of 5 kN. Shearing test was done by compressive load applied at ceramic-veneer interface using a metallic rod with half-circle end to enclose the veneer disc for more uniform stress distribution with cross-head speed of 0.5 mm/min (Fig. 1). Data were recorded using computer software.

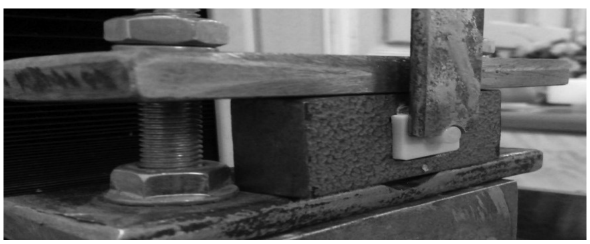

Figure 1: Mounted samples on a computer controlled Universal testing machine.

Color evaluation:

The color of the samples was measured using a reflective spectrophotometer (X-Rite, model RM200QC, Neu-Isenburg, Germany) (Fig. 2). A white background was selected and measurements were made according to the CIE L*a*b* color space.

Figure 2: Portable Reflective Spectrophotometer

All samples were placed in autoclave (Autoclave WOSON class N, China) and exposed to a humid environment (distilled water) under specific time (5 hours) and temperature (134°C). Samples that artificially aged were ready for the same color and shear bond strength measurements as done in non-aged samples.

STATISTICAL ANALYSIS:

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0 (IBM Corporation , NY , USA).

Qualitative data were described using number and percent. The Kolmogorov-Smirnov test was used to verify the normality of distribution Quantitative data were described using range (minimum and maximum), mean, standard deviation and median.

Significance of the obtained results was judged at the 5% level.

RESULTS:

Student t-test and Paired t-test were used for comparing variables affecting shear bond strength and color stability mean values (material type and artificial accelerated aging).

Effect of aging on shear bond strength:

Table (1): shear bond strength result (Mean ± SD) as a function of bond non-aged and bond aged for each veneering material used.

Shear bond strength (Mpa)	Bond non-aged (n = 10)	Bond aged (n = 10)	p
Composite group (Mean ± SD)	13.09 ± 1.66	3.54 ± 0.97	<0.001***
porcelain group (Mean ± SD)	15.01 ± 1.85	10.28 ± 1.40	<0.001***

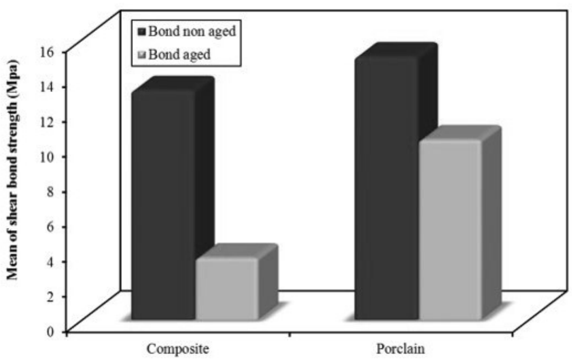

Figure 3: Histogram of shear bond strength mean values as a function of bond non-aged and bond aged for each veneering material used.

It was found that; a very highly significant difference in shear bond strength mean values between non-aged and aged porcelain veneered zirconia samples (P <0.001), with higher mean value for non-aged samples (15.01 ± 1.85 Mpa) than aged samples (10.28 ± 1.40 Mpa).

A very highly significant difference in shear bond strength mean values between non-aged and aged composite veneered zirconia samples (P <0.001), with higher mean value for non-aged samples (13.09 ± 1.66 Mpa) than aged samples (3.54 ± 0.97 Mpa).

Effect of aging on color stability:

Table (2): color result (Mean ± SD) as a function of material type (after aging).

Color results (ΔE)	Composite (n = 10)	Porcelain (n = 10)	p
Mean ± SD.	9.42 ± 1.40	4.28 ± 1.01	<0.001***

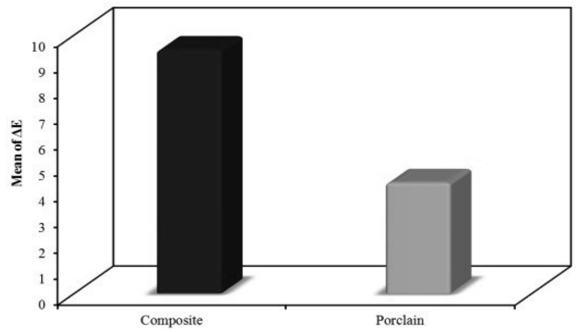

Figure 4: Histogram of color results mean values as a function of material type (after aging).

It was found that; a very highly significant difference in color stability results of the samples after aging (P <0.001), with higher color stability mean value for porcelain veneered zirconia group (ΔE = 4.28 ± 1.01) than composite veneered zirconia group (ΔE = 9.42 ± 1.40).

DISCUSSION:

The increased dental awareness of the public and their ever-increasing demand for esthetic restorations that look like the natural teeth have fueled the search for more esthetic dental materials and techniques over the past decades [16-18].

Zirconia based restoration is one of the esthetic materials that could be used as a substructure of posterior FPDs due to the high mechanical properties it has [19].

In the present study, 40 samples of zirconia for shear bond strength test were sawed with final dimensions (2 mm) thickness. Samples were further veneered with porcelain VM9 and bredent crealign composite discs with dimensions (5 mm) diameter, (3 mm) using a custom-made metal mold. These samples were manufactured according to data supplied by literatures [20-23]. Also, 20 samples of zirconia for color stability test were sawed with final dimensions (1 mm) thickness. Samples were further veneered with porcelain VM9 and bredent crealign composite with final dimensions (1 mm) thickness using a custom-made metal mold. These samples were manufactured according to data supplied by literatures[15, 24].

Sandblasting of zirconia was done by 110 μm and 50 μm particle size alumina for the veneering crea lign composite and veneering porcelain respectively at 0.2 MPa for 20 seconds according to manufacturer instructions and data supplied by literatures (25-27).

Shear bond strength between veneering materials (crea lign composite, porcelain VM9) and zirconia framework was measured before and after hydrothermal aging by autoclave, in order to assess the clinical durability of veneered restorations to zirconia framework.

Autoclaving at 134∘C for 5 hours is the standard aging protocol according to ISO 13356 valid for YTZP implants for surgery. Autoclave aging at 134∘C for 5 hrs simulates oral conditions for 15 years (28).

In this study, SBS test method was selected because of its simplicity, such as the ease of specimen preparation, simple test protocol and the ability to rank different products according to bond strength values (22).

Spectrophotometer (SP) was used for measuring the difference in color of the samples before and after autoclave aging. This device is used to measure the color in numbers, which makes color selection easier and reliable (29).

Effect of aging on SBS of porcelain veneered zirconia group:

Based on the results obtained from this study, the first null hypothesis was rejected. There was a significant difference in the mean values of SBS between aged (10.28 ± 1.40 Mpa) and non-aged (15.01 ± 1.85 Mpa) porcelain veneered zirconia groups. The values of our study are in disagreement with the results were obtained by studies done by Manoti et al.(2016) [28] and Yong et al.(2012) [30] which concluded that no significant difference was found in SBS between aged and non-aged groups. This difference may be attributed to the difference in materials and methods which were used in these studies.

The low thermal conductivity of zirconia engenders thermal accumulation upon cooling process and results in a high tensile stress at the interface which likely induces zirconia phase transformation that affects the bond strength [31].

Difference in coefficient of thermal expansion (CTE) between the veneering porcelain and zirconia core results in high compressive stress at the interface which likely induces zirconia phase transformation that affects the bond strength [31].

Recent studies have shown an indication that water molecules have an influence on the bond between veneered and veneering material. Water molecules can penetrate the zirconia lattice during exposure in a humid atmosphere which affects the bond strength [32].

Effect of aging on SBS of composite veneered zirconia group:

The results of our study showed that there was a significant difference in the mean values of SBS between aged (3.54 ± 0.97 Mpa) and non-aged (13.09 ± 1.66 Mpa) composite veneered zirconia groups with significant decrease of SBS values of aged group, P 0.05 <. Results were found to be in agreement with study done by Komine et al. (2009) [33].

Induced thermal stresses and water molecules penetration during aging process may affect the bond strength between zirconia and veneering composite [32]. Aging process may produce internal porosity within the composite material which will affect the bonding mechanism.

Effect of aging on color stability:

The second part of the null hypothesis was not accepted because the results showed that the color was affected significantly after artificial accelerated aging of both materials. Composite veneered zirconia group showed the greater amount of color change with a mean ΔE* value of (9.42) more than porcelain veneered zirconia group which have mean ΔE* value of (4.28).

Significant color changes in the two groups were in disagreement with results found in previous studies [15, 24]. It may be attributed to different materials and methods of aging used.

Color changes in porcelain group can occur due to the metal oxide content. Metal oxides are added to the ceramic to obtain appropriate color shades. It is known that the metal oxide bond could easily break down under heat, humidity and pressure. Peroxide compounds would then form and would likely change the color of the porcelain [34]. Color changes in composite group may be attributed to the chemical composition of the composite material and its resin content which may play a role in the way the material reacts to the accelerated aging process. The resin matrix is a polymer-based substance and may undergo surface degradation and roughening as a result of artificial accelerated aging. This degradation and roughening would likely change the color of the composite veneer [35].

One of the limitations of this study was that, our tests were done outside the patient mouth which not simulated the clinical oral condition. Another limitation was the only layering technique was used, more types of veneering techniques may be useful in future studies.

CONCLUSION:

Within the limitation of this study, the following conclusions could be drawn:

1. Porcelain veneered zirconia ceramics had higher color stability and shear bond strength than composite veneered zirconia ceramics.

2. Color stability and Shear bond strength of veneered zirconia ceramics were significantly decreased after artificial accelerated aging.

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