Al-Azhar Journal of Dentistry

Manuscript 1606

Restorative Dentistry Issue (Removable Prosthodontics, Fixed Prosthodontics, Endodontics, Dental Biomaterials, Operative Dentistry)

Effect of Hydrothermal Degradation on Translucency of Zirconia Laminate Veneers

Esraa S. Mostafa

Osama S. Abd-Elghany

Sara Tamimi

Effect of Hydrothermal Degradation on Translucency of Zirconia Laminate Veneers

Esraa S. Mostafa [a,*], Osama S. Abd-Elghany [b], Sara Tamimi [b]

[a] Health Insurance, Cairo, Egypt
[b] Department of Crowns and Bridges, Faculty of Dental Medicine for Girls, Al-Azhar University, Cairo, Egypt

Abstract

Purpose: The present study aimed to assess the effect of hydrothermal degradation on the translucency of zirconia laminate veneers. **Patients and methods:** A total of 30 discs of zirconia laminate veneers (thickness: 0.5 mm) were obtained from high-translucent zirconia, super translucent zirconia, and ultra-translucent zirconia. The samples were divided into three groups ($n = 10$) according to the translucency of the material; group (1) High Translucent Multi Layered katana zirconia, group (2) Super Translucent Multi Layered katana zirconia, and group (3) Ultra Translucent Multi Layered katana zirconia. The shade of each group was A1. All the groups were subjected to hydrothermal degradation (134 ± 2 °C at 0.2 MPa) for 5 h. The translucency of the samples was measured using a reflective spectrophotometer. **Results:** Statistical analysis using the analysis of variance test showed no significant effect on the translucency of all the tested groups after hydrothermal degradation. **Conclusion:** Hydrothermal degradation does not affect the translucency of zirconia (High Translucent Multi Layered, Super Translucent Multi Layered, and Ultra Translucent Multi Layered).

Keywords: Hydrothermal degradation, Laminate veneers, Translucency

1. Introduction

Zirconia has three different crystallographic layouts that change depending on the temperature. The tetragonal stage (at temperatures ranging from 1170 to 2370 °C) has high mechanical properties, the monoclinic stage (constant from 1170 °C to room temperature) has the lowest mechanical properties, and the cubic stage (from 2,370to the melting point 2680 °C) has intermediate mechanical properties. Therefore, it is essential to maintain zirconia in cubic or tetragonal phases for better mechanical properties [1].

However, hydrothermal degradation or low thermal degradation (LTD) causes destabilization of zirconia when there is water or water vapor and moisture which leads to tetragonal, monoclinic transformation (t-m) transformation causing the increase of monoclinic content and surface roughness and leading to premature failure [2].

The hydrothermal degradation of Yttria Stabilized Zirconia Y-TZP is affected by its yttria content and cubic phases. Zirconia ceramic is more vulnerable to LTD when stabilizer content (such as yttria) is reduced. Increased yttria content, on the other hand, slows the tetragonal monoclinic phase transformation and thus improves Y-TZP ageing resistance [3].

A fully stabilized zirconia dental material with more than 8% yttria and a highly translucent 6-mol % yttria Partial Stabilized Zirconia PSZ dental material was recently introduced. Translucency is increased in fully stabilized zirconia due to its more stable cubic phase. Another benefit of cubic crystals is that they have fewer grain borders than tetragonal crystals, which is where light scattering occurs [4].

In 2015, two new products based on cubic zirconia formulation were introduced: cubic ultra-translucent (UT) and super translucent (ST) zirconia. Both products have multilayered versions (UTML and STML). UT and ST zirconia significantly advance the aesthetic, minimally invasive monolithic computer-aided design/computer-aided manufacturing (CAD/CAM) restorations [5].

Received 30 October 2022; accepted 15 January 2023.
Available online 17 May 2024

* Corresponding author. Al-Azhar University Girls Branch, Faculty of Dental Medicine for Girls, Nasr City, Egypt.
E-mail address: EssraaMostafa.8521@azhar.edu.eg (E.S. Mostafa).

https://doi.org/10.58675/2974-4164.1606

This vitro study aimed to assess hydrothermal degradation's effect on the translucency of zirconia laminate veneer HTML, STML, and UTML zirconia. The null hypotheses proposed for the present study was that there would be no significant differences in translucency among the various tested groups.

2. Patients and methods

2.1. Sample size calculation

To evaluate the translucency of different types of zirconia laminate veneers after hydrothermal degradation; an analysis of variance (ANOVA) test or an equivalent nonparametric test will be used for comparison between two Zirconia groups and lithium disilicate. According to a previous study [6], the percentage (%) of total translucency ranged from 6.5 ± 0.4, 23.4 ± 0.2 in the Zirconia groups to 28.3 ± 0.6 in the lithium disilicate, e.max press LT (LDLT) group. After hydrothermal degradation, the values ranged from 8.9 ± 1.2 to 22.6 ± 0.9 and 28 ± 0.9. Using G power statistical power Analysis program (version 3.1.9.7) for sample size determination [7]. A total sample size of 30 (n = 10 in each group) will be sufficient to detect a medium effect size of 0.63, with an actual power (1-β error) of 0.8 (80%) and a significance level (α error) 0.05 (5%) for the two-sided hypothesis test.

2.2. Fabrication of zirconia samples

Thirty multilayered translucent katana zirconia (HTML, STML, UTML) samples were milled in the form of discs with a diameter of 8 mm and a thickness of 0.5 mm of color A1 using CAD/CAM milling machine. The katana block has been inserted into the CAD/CAM Roland machine (Roland, Japan), with 10 discs from each type of zirconia block.

According to manufacture instructions, the Ultra-translucent zirconia discs milled with 24.6 oversize to compensate for the expected sintering shrinkage, the super translucent zirconia disc milled with 22.6 oversize and the multilayered zirconia discs milled with 23.5 oversize. According to the constructor's references, the partially sintered samples were fully sintered in a high-temperature furnace (TABEO-1/S/ZIRKON-100, Mihomvogotm, Germany) at 1450–1550 °C for 16 h as shown in (Fig. 1).

Finishing of samples was done using diamond finishing stone at low speed using low pressure twice on each sample surface in one direction. The glazing of the samples was carried out by applying the (Cerabien ZR glazing material)over each disc, then inserted into the (Ivoclar Vivadent furnace) with a starting temperature of 600 °C and increasing gradually till reaches 850 °C.

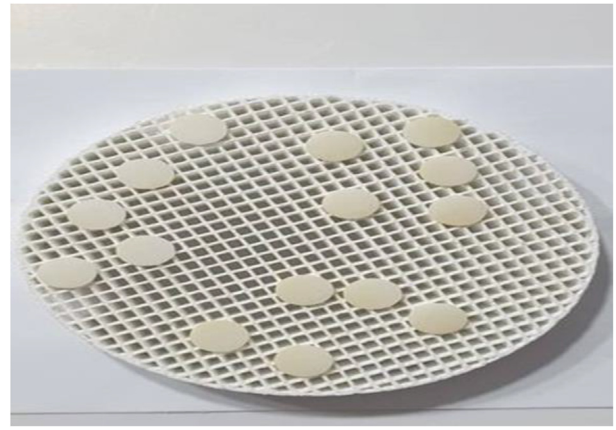

Fig. 1. Samples after sintering.

2.3. Experimental design

Thirty (N = 30) multilayered KATANA zirconia discs were made up. Samples were divided into three groups (n = 10) according to translucency as follows:

(a) Group (1): High translucent zirconia (HTML) $n = 10$.
(b) Group (2): Super translucent zirconia (STML) $n = 10$.
(c) Group (3): Ultra translucent zirconia (UTML) $n = 10$.

2.4. Testing procedure

2.4.1. Translucency parameter (TP)

The translucency of the samples was measured by a movable reflective (spectrophotometer). The aperture size was set to 8 mm, and the samples were aligned with the device. The samples were placed in the center of the measuring port and were kept in the same position for the white and black backings.

The measurements were performed at the center of each specimen over a white (CIE L* = 88.81, a* = −4.98, b* = 6.09) and black backing (CIE L* = 7.61, a* = 0.45, b* = 2.42) relative to the CIE standard illuminant D65.

The translucency parameters (TP) values were obtained by calculating the color difference of the specimens over black and white backgrounds by using the following equation: TP = [(Lb* − Lw*) 2+(ab* − aw*) 2+(bb* − bw*) 2]1/2.

2.5. Hydrothermal degradation of the samples

The samples of each group were subjected to a hydrothermal degradation procedure using an autoclave (TS-Tau sterile autoclave, Fino Moransco-COMO, Italy). The samples were packed in sterilized labeled packs and then inserted on the autoclave trays.

The program of the autoclave was set at 134 °C, under 2 bar pressure, and for 5 h. After cooling, the samples were packed in an airtight glass container until testing.

2.6. Translucency determination (TP value)

After all the samples were subjected to aging (hydrothermal degradation), the measurement of translucency was carried out for the second time by spectrophotometer to compare the translucency of each group before and after hydrothermal degradation to determine how aging affects translucency.

2.7. Statistical analysis

Numerical data were explored for normality by checking the distribution of data and using tests of normality (Kolmogorov–Smirnov and Shapiro–Wilk tests). Data showed parametric distribution. Data were presented as mean and SD values. Repeated measures ANOVA test was used to study the effect of zirconia translucency, hydrothermal degradation, and their interactions on the TP. Bonferroni's post hoc test was used for pair-wise comparisons when the ANOVA test was significant. The significance level was set at P less than or equal to 0.05. Statistical analysis was performed with IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

3. Results

3.1. Effect of hydrothermal degradation regardless of zirconia translucency

Regardless of zirconia translucency; statistically there was no significant change in mean TP after hydrothermal degradation (P value = 0.213, effect size = 0.037) as shown in Table 1 and (Fig. 2).

Table 1. The mean, D values, and results of repeated measures analysis of variance test for comparison between translucency parameter values before and after hydrothermal degradation regardless of zirconia translucency.

Before hydrothermal degradation		After hydrothermal degradation		*P* value	Effect size *(Partial eta squared)*
Mean	SD	Mean	SD		
22.2	4.44	23.36	3.55	0.213	0.037

*: Significant at P less than or equal to 0.05.

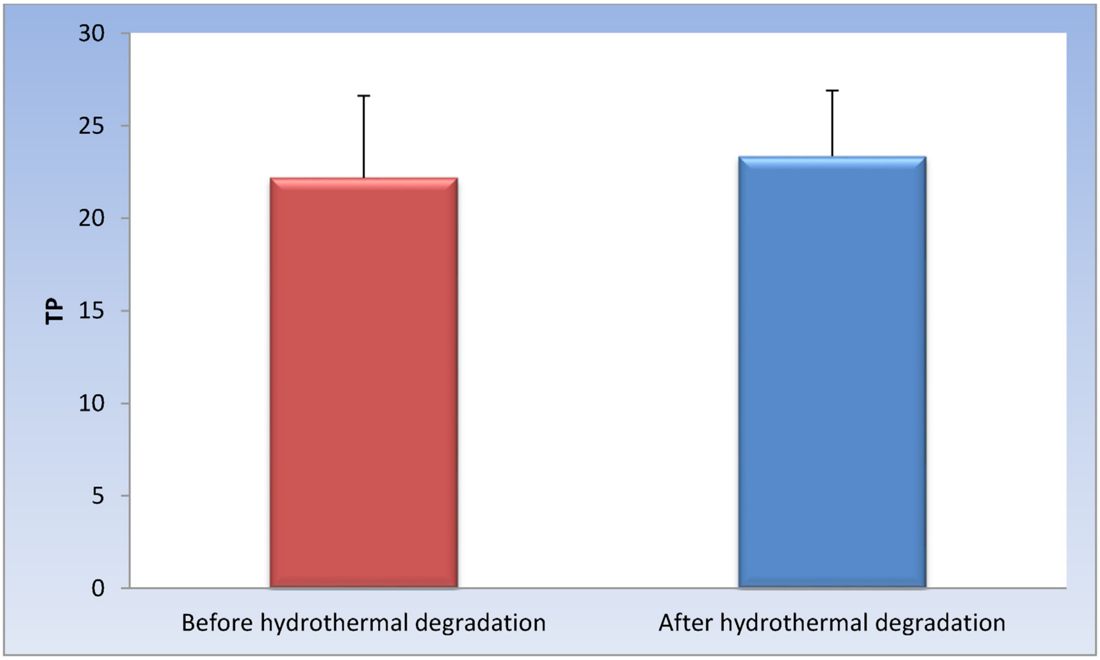

Fig. 2. Bar chart representing mean and standard deviation values for translucency parameter before and after hydrothermal degradation regardless of zirconia translucency.

3.2. Effect of different interactions on TP

3.2.1. Effect of hydrothermal aging

Whether with translucent, STML or UTML zirconia; statistically there was no significant change in mean TP after hydrothermal degradation (P value = 0.079, Effect size = 0.071), (P value = 0.324, Effect size = 0.023) and (P value = 0.549, Effect size = 0.009), respectively as shown in Table 2 and (Fig. 3).

Ethics code: REC-CR-22-08.

4. Discussion

To improve esthetics, new zirconia materials with increased Translucency have been introduced to the market [8]. Translucent zirconia of recent generations is adaptable and appropriate for a variety of restorations, including monolithic crowns and anterior esthetic restorations [9].

One of these generations, known as multilayered, a single block is milled to show layers of polychromatic, transparent zirconia that range in colour from enamel to dentine. This contemporary multilayered zirconia allows for anterior and posterior restorations [10].

The integrated color gradient, when compared with a single-color block, greatly simplifies the individual characterization of the restoration. To achieve the most aesthetically pleasing results, a multilayered material should only go through one combined stain and glaze procedure [11].

STML and UTML zirconia is a highly aesthetic material with exceptional mechanical properties. Because of its favorable properties and minimal tooth preparation, monolithic translucent zirconia ceramic is frequently used in restorative dentistry. It can be used in minimally invasive restorations that require less tooth reduction and material thickness without sacrificing strength [12].

The translucent zirconia was represented in this investigation by the KATANA blanks; Kuraray Noritake Dental Inc., the specimens with the disc shape were from the second generation HTML

Table 2. The mean, SD values, and results of repeated measures analysis of variance test for comparison between translucency parameter values before and after hydrothermal aging with each zirconia translucency.

Hydrothermal degradation	Translucent zirconia		Super-translucent zirconia		Ultra-translucent zirconia	
	Mean	SD	Mean	SD	Mean	SD
Before hydrothermal degradation	20.17	2.47	22.35	5.55	24.09	4.1
After hydrothermal degradation	23.01	3.26	23.93	4.11	23.13	3.41
P value	0.079		0.324		0.549	
Effect size *(Partial eta squared)*	0.071		0.023		0.009	

*: Significant at P less than or equal to 0.05.

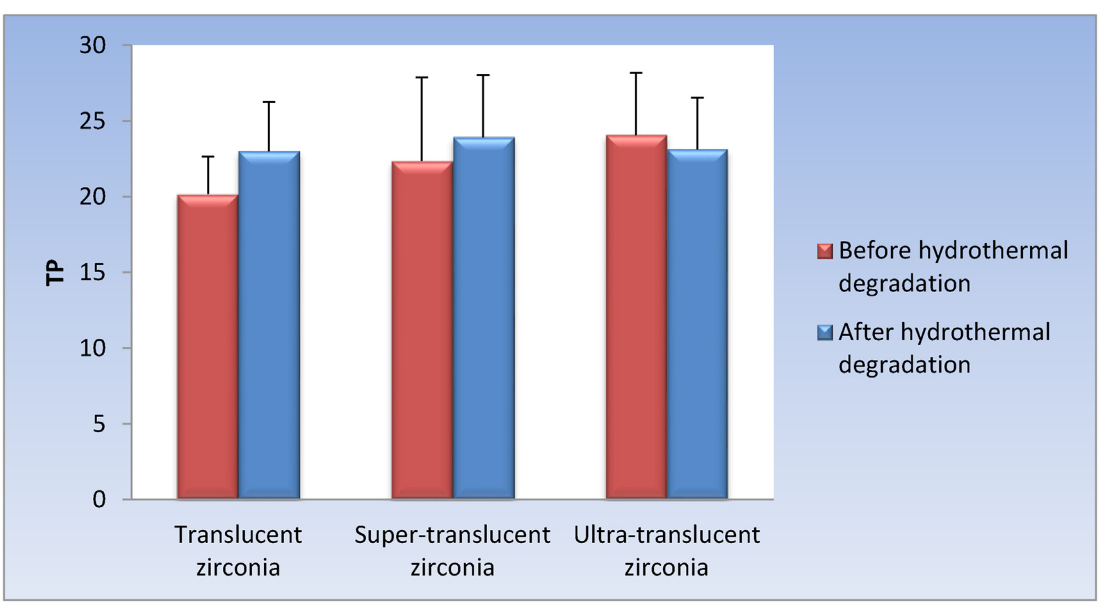

Fig. 3. Bar chart representing mean and standard deviation values for translucency parameter before and after hydrothermal aging with each zirconia translucency.

katana zirconia and third generations STML katana zirconia, and UTML katana zirconia.

The three materials were very different, STML 4Y-PSZ with 65 weight percent cubic content and a 2.81 (±0.17) micron grain size, UTML 5Y-PSZ (5 mol% Y-PSZ) with 75 weight percent cubic content and a 4.05 (±0.85) micron grain size, and ML: 3Y-PSZ with less than 50 weight percent cubic content and a 0.63 (±0.03) micron grain size. Tetragonal crystals made up the majority of ML3Y-PSZ, while cubic material was present in STML and UTML [13].

The sintering of zirconia samples was done at a temperature furnace at 1450–1550 °C as in the temperature above, causing grain boundary cracks to form, leading to light scattering and decreased translucency [14].

The finishing and polishing of samples were done in one direction by one operator because using diverse measurement tools and polishing techniques affects the TP of the material [15].

The use of a reflective spectrophotometer to obtain CIELAB coordinates is expected in dental research; thus, it was used in the present study to obtain TP for the samples from various groups.

Aging of zirconia (hydrothermal degradation) is unavoidable as it is moistness and temperature dependent and occurs at 37 °C during the lifetime, causing volume expansion of grains, surface roughness, and micro-cracking of conventional zirconia; as recommended in many studies, aging is done by autoclave as it induces low thermal degradation in zirconia at 134 °C [16].

In the present study, all the samples (UTML, STML, HTML) received aging (hydrothermal degradation) in an autoclave for 5 h at 134 °C to conduct the accelerated aging protocol. More than one author [17] considered the treatment of zirconia samples in an autoclave for 1 h at 134 °C as equivalent to 3–4 years of *in vivo* aging. Therefore aging for 5 h is equivalent to 20 years in the patient's mouth [18].

The present study's results revealed no considerable difference in the translucency of zirconia samples of different groups (HTML, STML, and UTML) after hydrothermal degradation. The null hypothesis was accepted that there would be no significant difference in translucency after hydrothermal degradation. These results follow the results of other studies [18–20] that hydrothermal degradation does not affect the translucency of tested zirconia samples.

The translucency is not affected by hydrothermal degradation because there was no monoclinic phase was revealed in 5Y-TZP. High-translucent katana zirconia, super-translucent katana zirconia, and ultra-translucent katana zirconia when tested under more extreme LTD conditions did not form a monoclinic phase even after hydrothermal aging at 134 °C for 100 h. These results imply that 5Y-TZP has a higher aging resistance. This effect is due to the higher yttria content of the former material, which prevents the low-temperature degradation of Y-TZP, as KATANA contained a high-level of cubic phase before and after aging.

The results of the present study are similar to those obtained for KATANA in a previous study [21]. Higher yttria content results in a rise in the zirconium dioxide (ZrO_2) content, which increases materials translucency and ageing resistance. The resistance of Y-TZP against LTD is determined by factors other than the yttria content, such as the additional content of alumina. The tetragonal to monoclinic phase transformation is dependent on the addition of alumina. This could justify the more significant confrontation to degradation by prevention of monoclinic phase transformation since tetragonal zirconia is generally supersaturated with alumina to increase its aging performance and strengthen grain margins [22].

The finding was inconsistent with a previous study [23] which reported that the Translucency did not decrease after the aging of cubic zirconia, which is probably associated with the decrease in the amount of transformation of zirconia from the tetragonal to the monoclinic phase, and this is accompanied by decreased superficial irregularity, light scattering, and reflection.

Moreover, because of the decrease in the transformation from tetragonal to monoclinic phase, microcracks and superficial porosity could also be diminished, resulting in no change in translucency. Furthermore, porosity is one of the main factors that has an impact on the translucency of ceramics after aging, as seen by some authors [24].

Contrary to another study's findings [25], which indicated that hydrothermal ageing affected the optical properties and microstructures of precolored monolithic zirconia ceramics and that translucency rose slightly with time, these results contradict each other. The production of cubic zirconia may be promoted, leading to higher TP values with longer aging times, as a result of the reduced light scattering from the cubic zirconia grain boundaries caused by the presence of some metal oxides, such as coloring pigments.

The present study is not free from limitations. One of these limitations is that only one cubic zirconia brand used in this study provides these results.

Other high translucent zirconia brands with different compositions may provide different results under simulated oral aging.

4.1. Conclusions

It was concluded from the present study that hydrothermal aging did not affect the translucency of HTML zirconia, STML zirconia, and UTML zirconia.

Recommendations

Clinically relevant restoration and different prosthetic designs should be investigated rather than the disc-shaped samples.

Funding

The authors declare that this scientific piece of work did not receive any funding support from any party.

Conflicts of interest

There was no conflict of interest.

Acknowledgments

I would like to express my deepest thanks and respect to Dr Mohammed Abbas professor of Dental Materials, Faculty of Dental Medicine for Boys, Al-Azhar University for his guidance and input throughout the process of this research and especially for his patience.

References

[1] Kim HK, Kim SH. Effect of hydrothermal aging on the optical properties of precolored dental monolithic zirconia ceramics. J Prosthet Dent 2019;121:676−82.
[2] Inokoshi M, Shimizu H, Nozaki K. Crystallographic and morphological analysis of sandblasted highly translucent dental zirconia. Dent Mater 2018;34. 508−1.
[3] Kolakarnprasert N, Kaizer MR, Kim DK, Zhang Y. New multilayered zirconia's composition, microstructure and translucency. Dent Mater 2019;35:797−806.
[4] Papageorgiou K, Fasoula M, Kontonasaki E. Translucency of monolithic zirconia after hydrothermal aging: a review of in vitro studies. J Prosthodont 2020;29:489−500.
[5] Sulaiman T, Abdulmajeed A, Donovan A, Ritter T, Vallittu PK, Närhi TO. Optical properties and light irradiance of monolithic zirconia at variable thicknesses. Dent Mater 2015;31:1180−7.
[6] Harada K, Raigrodski AJ, Chung KH, Flinn BD, Dogan S, Mancl LA. A comparative evaluation of the translucency of zirconias and lithium disilicate for monolithic restorations. J Prosthet Dent 2016;115:215−23.
[7] Eduardo J, Amarante V, Venícius M, Pereira S, Mendonça G, Souza D, et al. Effect of hydrothermal aging on the properties of zirconia with different levels of translucency. J Mech Behav Biomed Mater 2020;109:103847.
[8] Jurado C, Tinoco J, Watanabe H, Hernandez R, Tsujimoto A. Novel translucent monolithic zirconia fixed restorations in the esthetic zone. Clin Case Rep 2022;10:1−6.
[9] Almutairi R, Elhejazi A, Alnahedh H, Maawadh A. Effects of different air particle abrasion protocols on the biaxial flexural strength and fractography of high/ultra-translucent zirconia. J Mater 2021;65:401−9.
[10] Ziyad T, Abu-Nabaa L, Almohammed S. Optical properties of CAD-CAM monolithic systems compared: three multi-layered zirconia and one lithium disilicate system. Heliyon J 2021;7:E08151. 2−7.
[11] Rinke S, Metzger A, Ziebolz H. Multilayer super-translucent zirconia for chairside fabrication of a monolithic posterior crown. Case Rep Dent 2022;10(7):2−10.
[12] Abdel-Aziz M. Effect of different surface treatments on color stability of ultra-translucent zirconia occlusal veneers before and after thermocycling aging. Egypt Dent J 2022;68:1757−66.
[13] Liu H, Inokoshi M, Nozaki K. Nfluence of high-speed sintering protocols on Translucency, mechanical properties, microstructure, crystallography, and low-temperature degradation of highly translucent zirconia. Dent Mater J 2022;38:451−68.
[14] Stawarczykn B, Liebermann A, Eichberger M, Guth J. Evaluation of the mechanical and optical behavior of current esthetic dental restorative CAD/CAM composites. J Mech Behav Biomed Mater 2015;11:1−9.
[15] Chen C, Chen Y, Lu Z, Qian M, Xie H, Tay FR. The effects of water on degradation of the zirconia-resin bond. J Dent 2017; 64:23−9.
[16] Chevalier J, Cales B, Drouin JM. Low temperature aging of Y-TZPceramics. J Am Ceram 1999;82:2150−4.
[17] Elkallaf E, Ahmed A, Essam E, Hassan S. Efficacy of different surface treatments on the bond Strength of Resin cement to Zirconia Ceramic. Al-Azhar D J 2020;4:501−10.
[18] Shen J, Xie H, Yang J. Evaluation of the effect of low temperature degradation on the translucency and mechanical properties of ultra-translucent 5Y-TZP ceramics. J Ceramic Int 2020;46:553−9.
[19] Ahmed D, Mandour M, El sharkawy Z. Optical properties and flexural strength of artificial aged tetragonal -cubic ultra-translucent zirconia. Al-Azhar D J 2020;1:135−42.
[20] Kanpalta B, Burduroglu D, Kara O. Effect of artificial aging on the Translucency of monolithic zirconia materials sintered at different temperatures. J Prosthet Dent 2022;128:1−91.
[21] Ibrahem A, Mandour M, El mekkawy W. Optical properties of zirconia monolithic crowns constructed using speed sintering cycl. Al-Azhar D J 2022;2:211−7.
[22] Zhang F, Vanmeensel K, Batuk M, Hadermann J, Inokoshi M, Van Meerbeek B, et al. Highly translucent, strong and aging-resistant 3Y- TZP ceramics for dental restoration by grain boundary segregation. Acta Biomater 2016;16:215−22.
[23] Lucas T, Lawson N, Janowski G, Burgess J. Phase transformation of dental zirconia following artificial aging. J Biomed Mater Res, Part B 2015;103:1519−23.
[24] Bachhav V, Aras M. The effect of ceramic thickness and number of firings on the color of a zirconium oxide based all ceramic system fabricated using CAD/CAM technology. J Adv Prosthodont 2011;3:57−62.
[25] Shehata W, Abdel Aziz S, El naggar G, Abdel Gahny O. Effect of sandblasting and zirconia primer application on the zirconia-cement shear bond strength (An in-vitro Study). Al-Azhar D J 2018;2:187−94.