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Comparison of Color Stability between Monolithic Zirconia Stained and Glazed with MiYO Esthetic System and Lithium Disilicate Ceramic

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ABSTRACT

Background/Objective: CAD/CAM-made monolithic zirconia restoration has excellent mechanical properties but limited esthetic characteristics due to low translucency. Various techniques were undertaken to enhance their translucency and esthetic. Staining zirconia by MiYO liquid ceramic system is one of these techniques. This study aimed to evaluate the color stability of the MiYO-treated monolithic zirconia and compare it with layered lithium disilicate ceramic

*Material and Method: Thirty ceramic specimens were prepared in the dimension of (20mm*15mm*2mm) and divided into two groups, fifteen monolithic zirconia specimens stained at two color zones with MiYO esthetic system, and fifteen lithium disilicate specimens. Both groups were subjected to thermal aging. The CIE L*a*b* color parameters were measured using the dental spectrophotometer to determine the color stability by using the color difference (ΔE) formula:* $\Delta E= [(\Delta L^*)^2+(\Delta a^*)^2+(\Delta b^*)^2]^{½}$.

Results: The mean ± standard deviation of color difference (ΔE) for lithium disilicate, monolithic zirconia at zone one MiYO layer, and two MiYO layers were 1.59 ± 0.56, 2.34 ± 1.02, and 2.63 ± 1.25 after 1000 thermal cycles and 2.69 ± 0.97, 2.70 ± 1.18 and 3.51 ± 1.34 after 2000 thermal cycles respectively. After the 1000 thermocycling, a statistically significant difference of ΔE was found between groups (P<0.05). However, after 2000 thermal the difference in ΔE was considered statistically insignificant (P>0.05). No significant difference in ΔE was found in both zones of MiYO-stained zirconia in both stages.

Conclusion: Both groups showed clinically acceptable color stability (ΔE<3.7) despite the perceptible color change by the human eyes (ΔE>1).

Key words: Color stability, Esthetics, Lithium disilicate, MiYO stain, Monolithic zirconia

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INTRODUCTION

Esthetics and physical permanence are among the most important consideration for dental practitioners when choosing ceramics for dental restorations. Since their debut in the dental practice, ceramic materials are regarded to be the foundation of esthetic dentistry and their esthetic appearance is related to their capacity to accurately harmonize with natural teeth [1–3]. Glass-ceramic made of lithium disilicate is advisable for highly esthetic restorations which provide excellent translucency and color matching properties, but with lower mechanical properties, higher cost, and more complicated laboratory procedures than zirconia [4]. Yttria-stabilized tetragonal zirconia polycrystal (Y-TZP) is another well-known all-ceramic dental restoration material that meets the needs of patients looking for esthetic metal-free restorations as well as clinicians looking for a biocompatible and mechanically strong material [5].

Monolithic zirconia restorations can be made with a milling machine using computer-aided design and computer-aided machining (CAD/CAM) technology, which has high flexural strength, minimal wear on antagonists, fewer dental sessions and laboratory time, and because they are monolithic, they do not have the unwanted complication of chipping [6,7]. Nonetheless, their greatest drawback was the inability to achieve satisfactory translucency due to high crystalline content, resulting in low aesthetic performance [8]. Several strategies were used to address monolithic zirconia's white opaque color appearance, such as veneering using feldspathic porcelain for a more acceptable esthetic outcome, however, the cohesive failure between ceramic layers was the main problem [9]. Furthermore, improvements in the conventional zirconia formulation have produced a new class of monolithic zirconia with a higher level of translucency, different molecular structure, and physical characteristics than conventional zirconia, as well as a more esthetic appearance [10,11]. These include a decrease in alumina (Al2O3) content, a reduction in grain size, the eradication of porosity, and an increase in the cubic phase, the latter due to an increase in the quantity of yttrium oxide (Y2O3), which improves translucency but weakens mechanical properties [5].

Another method for achieving a natural appearance is to externally stain monolithic zirconia by brushing the outermost layer of the ceramic restoration with a thin layer of metal-oxide stains, coupled with the application of glazes to further characterize the restoration. The MiYO Liquid Ceramic comprised various self-glazing MiYO colors and structures, making it simple to match colors and provide the translucency and depth necessary for monolithic crowns in unprecedented thicknesses of 0.1mm-0.2mm without cutback or modifying CAD designs. A high esthetic result can be achieved to monolithic zirconia with MiYO that is comparable to layered restorations; However, this thin coating of stain and glaze may gradually wear off when subjected to temperature changes, toothbrush abrasion, and mechanical loading in the oral environment [3,12].

The quality or value of the service delivered to the patient may be impacted by changes in the glossiness and color stability of the dental restoration, particularly if the change exceeds the recommended threshold established to aid clinicians in assessing the predictability and esthetic quality of restorations in the esthetic zone [13]. The study aims to compare color stability between monolithic zirconia (Y-TZP) stained and glazed by MiYO liquid ceramic system and lithium disilicate ceramic before and after 1000 and 2000 thermal cycles.

MATERIAL AND METHOD

Specimens preparation

Fifteen lithium disilicate specimens and fifteen (Y-TZP) monolithic zirconia specimens stained with MiYO esthetic system were prepared in the dimension of (20mm X 15mm 2mm) as shown in (Figure 1).

The monolithic zirconia specimens were prepared from partially sintered (20%) Zirkonzahn prettau® zirconia block (Zirkonzahn GmbH, Bruneck, Italy) using a CAD/CAM milling machine (M5 Heavy Metal Milling Unit, Zirkonzahn, Bruneck, Italy) under dry milling according to manufacturer’s instruction. After the milling process, all the specimens are checked with a digital caliper (Insize digital caliper) so that any mismatching had been corrected until becomes (20mm * 15mm * 2mm). MiYO liquid ceramic was applied only to one surface (working surface). The surface was sandblasted with glass beads at 50 µm, 2 bar pressure, and 20 seconds, cleaned with distilled water in an ultrasonic bath, and dried carefully with a steam cleaner according to the manufacturer's instructions. The MiYO colors were mixed thoroughly with a metal-free spatula (MiYO mixing spatula), then the entire working surface was colorized with the special brush (MiYO Liquid Ceramic Brushes) in two color zones: one zone with Trans Clementine (1 color layer) and second zone with Trans storm in addition to mamelon coral (2 color layers) and fired (Figure 2). After that, the glaze paste was applied and fired. The prepared zirconia specimens will be fired using a ceramic furnace (Programat EP 5010; Ivoclar Vivadent, Schaan, Liechtenstein) with the following parameters: 450 °C starting temperature, 720 °C final temperature, 2 minutes dry time, 4 minutes closing time, 1 minute opening time, 40 seconds holding time and 45 °C/min heating rate.

The Lithium disilicate specimens were fabricated in two-layer (bilayered), the core (20mm length, 15mm width, and 1 mm thickness) fabricated by heat pressing technique. Lithium disilicate dental material (Amber® Press) has been used to fabricate the core. The second layer was fabricated by adding lithium disilicate enamel/dentin powder to the core using (Ivoclar IPS e.max Ceram) and fired. For standardization the lithium disilicate powder was applied to more than 1mm, after firing any excess was cut back to make all the specimens 2 mm thick which were controlled with a digital caliper (Insize digital caliper). Then a layer of glaze paste (IPS e.max Ceram Glaz) was added and fired.

Color stability measurements

The dental spectrophotometer (RayplickerHandy, by BOREA, France) (Figure 3) was used to measure the color coordinates L*, a*, and b* of the Commission Internationale de l'Éclairage (CIE) to determine the color changes. The included software automatically quantified the data, giving the red-green (a*), yellow-blue (b*), and brightness values (L*). The color difference (ΔE)

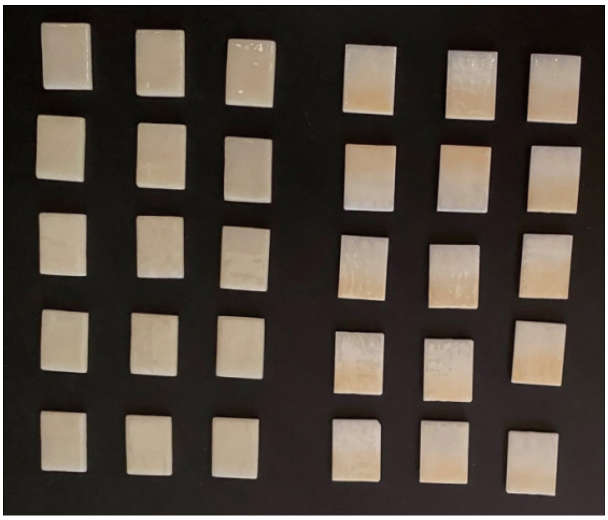

Figure 1: Lithium disilicate specimens on the left side and MiYO stained monolithic zirconia specimens on the right side.

formula $\Delta E= [(\Delta L^*)^2+(\Delta a^*)^2+(\Delta b^*)^2]½$ was used [14] for mathematical comparison of color. Where ΔL*, Δa*, and Δb* are the color parameters differences between specimens before and after different thermocycling. The measurement was recorded against a white background [15].

The color difference (ΔE) was determined at two locations per zirconia specimen: a zone of two layers of MiYO stain, and a zone of one layer of MiYO stain, and for the lithium disilicate specimens the measurement recorded at the center of the samples three times and the average was taken. The samples were placed in the black opaque container during measurement to block all external lights that may interfere with the readings and a light source illumination matching average daylight (D65) had been chosen [16]. The recorded images of samples were transferred to the specifically designed Rayplicker computer software for recording color parameters.

Thermocycling

All the specimens were exposed to thermal aging using a thermocycling device at a temperature of (5°C-55°C), 30 seconds of dwell time, and a quick transfer time according to ISO 11405 standards [17]. The aging cycles were conducted in about 1000 and 2000 thermocycles. After finishing each thermal cycle the color parameters were recorded as previously mentioned.

Statistical analysis

IBM SPSS 26 was used. Analysis of variables within the same group was carried out using the analysis of variance (ANOVA). Statistical analysis for comparing the variables between the study groups was carried out using the t-test for two independent samples. The level of significance was set at *P<0.05.

RESULTS

The means and standard deviations of L*, a*, and b* color parameters were shown in Table 1. Overall after thermal agings, the values went down slightly, the lithium disilicate group had higher values than the zirconia group before and after the thermocycling stages except for the (a*).

As shown in Table 2, the one-way ANOVA test showed a statistically significant difference in ΔE within the same study groups at different stages of the study (P<0.05). The means of color change (ΔE) for both groups at three different stages of the study were perceptible by human eyes because it was greater than 1 [18] but also within the clinically acceptable range as the ΔE<3.7 [19]. The

Figure 2: Application of MiYO colors to monolithic zirconia specimens.

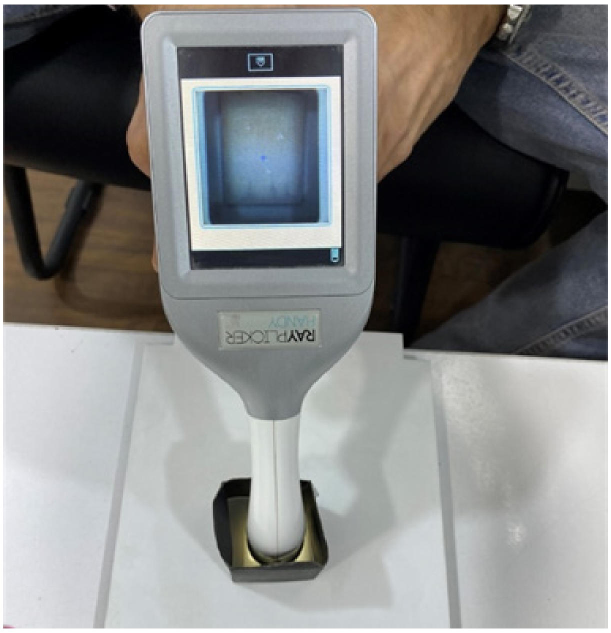

Figure 3: Recording the CIE Lab color parameters from the samples in the black opaque container against a white background.

Table 1: Mean and standard deviation of L*, a*, and b* per stage. (L* brightness values, a* red-green axis, b* yellow-blue axis).

Color parameters	Ceramic	Time		
		Before Thermocycling	After 1000 Thermocycling	After 2000 Thermocycling
		Mean (SD)	Mean (SD)	Mean (SD)
L*	Lithium Disilicate	70.233 (3.894)	70.307 (3.188)	70.267 (2.167)
	Zirconia at Zone of a One MiYO Layer	68.773 (4.278)	69.300 (2.615)	69.027 (2.149)
	Zirconia at Zone of a Two MiYO Layers	66.080 (3.256)	63.640 (3.114)	62.707 (3.133)
a*	Lithium Disilicate	1.287 (0.686)	1.373 (0.560)	1.093 (0.715)
	Zirconia at Zone of a One MiYO Layer	4.107 (0.694)	3.967 (0.630)	4.013 (0.496)
	Zirconia at Zone of a Two MiYO Layers	2.380 (0.497)	2.253 (0.352)	2.213 (0.452)
b*	Lithium Disilicate	19.640 (1.139)	19.233 (0.754)	18.640 (1.153)
	Zirconia at Zone of a One MiYO Layer	19.213 (1.757)	18.547 (1.415)	18.380 (1.626)
	Zirconia at Zone of a Two MiYO Layers	8.753 (1.138)	8.407 (0.747)	8.367 (0.675)

lithium disilicate group had a lower level of color change ΔE followed by the zirconia at the zone of one MiYO layer, with the greatest shift of color occurring at a zone of two MiYO layers of zirconia (Figure 4).

P-values for an independent t-test between the ceramic classes were shown in Table 3. ΔE was found to be significantly affected by ceramic types ($P<0.05$) after the first stage of thermocycling. Although there was a difference in ΔE between the ceramic groups after the second thermocycling, the difference showed no statistical significance ($P>0.05$). Also, the color difference ΔE at both zones of zirconia was compared and the distribution of both zones was similar and no statistically significant changes can be noticed ($P>0.05$) in all study stages.

DISCUSSION

Color stability of all-ceramic restorative materials is crucial due to the increasing demand for esthetics. The best restorative materials should be optimally stable mechanically and esthetically pleasing [20]. Staining techniques for enhancing monolithic zirconia appearance have been developed recently to meet patients' increasing demands for esthetics and affordable cost. In this in vitro study, the color stability of ceramics made of zirconia stained with the MiYO aesthetic system and lithium disilicate was evaluated and compared. For this purpose, spectrophotometry and the CIE L*a*b* color system were used because of their capacity to obtain measurements independent of the subjective influence of color [21]. Also, it allows clinical results to be interpreted, as the color change of this system is consistent with human color perception. [20] It had shown to be accurate and efficient when used in previous studies on the color of tooth-colored restorative materials [22,23]. As a result, this approach is highly accurate in terms of color analysis, and visual evaluation errors are rare [24].

In this study, the null hypothesis which claimed that thermocycling had a significant impact on the color stability of lithium disilicate and MiYO stained

Table 2: Mean, standard deviation, and one way ANOVA test for ΔE among stages.

Ceramic Types	ΔE (Baseline-First Stage)	ΔE (Baseline-Second Stage)	ΔE (First Stage-Second Stage)	One way ANOVA Test
	Mean (SD)	Mean (SD)	Mean (SD)	P-Value
Lithium Disilicate	1.597 (0.560)	2.693 (0.971)	1.745 (0.770)	*0.000
Zirconia (Zone 1)	2.349 (1.022)	2.702 (1.183)	1.433 (0.752)	*0.008
Zirconia (Zone 2)	2.6335 (1.250)	3.5159 (1.345)	1.5934 (0.642)	*0.001

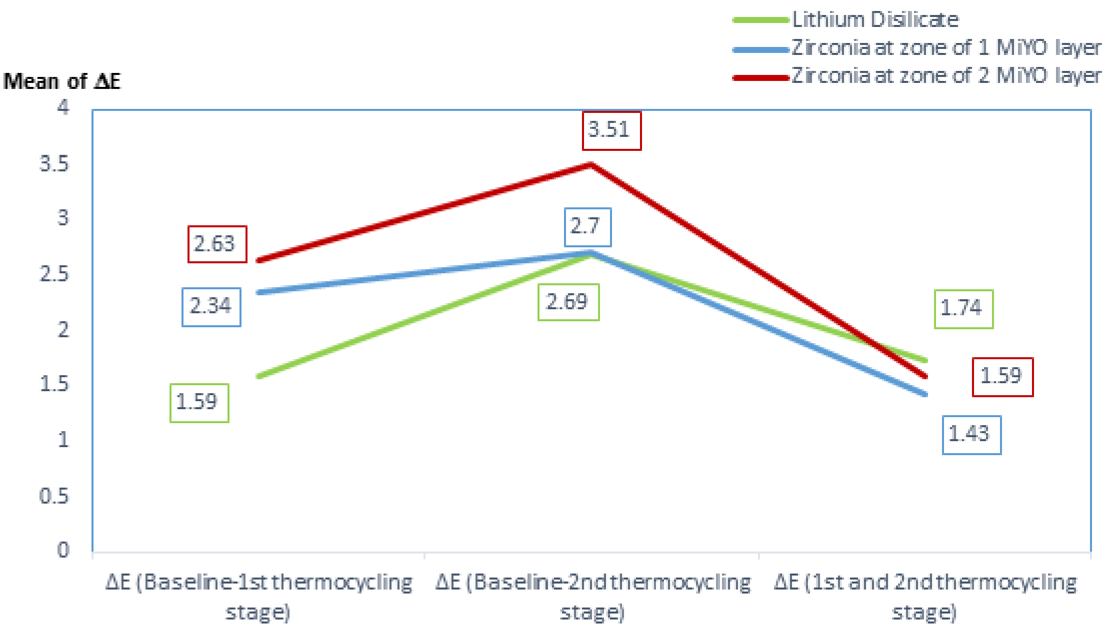

Figure 4: The distribution of ΔE for each study group at different stages was illustrated.

Table 3: P-value and Mean difference of independent T-test between study groups for ΔE in (Baseline, First stage), (Baseline, Second Stage), and (First Stage and Second Stage).

Ceramic groups	(Baseline- 1st Thermo cycling)	(Baseline-2nd Themocycling)	(1st Thermo cycling- 2nd Thermo cycling)
	Mean difference (P-value)	Mean difference (P-value)	Mean difference (P-value)
Lithium Disilicate Zirconia at one layer zone	-0.752 (*0.019)	-0.009 (0.982)	0.312 (0.271)
Lithium Disilicate Zirconia at two-layer zone	-1.037 (*0.007)	-0.823 (0.065)	0.151 (0.564)
Zirconia at one-layer zone Zirconia at two-layer zone	-0.285 (0.5)	-0.814 (0.09)	1.160 (0.535)

monolithic zirconia was rejected. Since less than 3.7 ΔE units (clinically acceptable value) [19] color changes upon thermocycling were found. However, none of the ceramics achieved the highest esthetic standards. Because the deviations were higher than the limit at which a color difference could be seen with the naked eyes in a laboratory setting (ΔE=1) [18].

In the present study, thermocycling aging resulted in the slightly decreasing CIE L*a*b* color parameters for both groups which means slightly shifting colors toward black for the L* axis, toward green for a* axis, and toward blue for the b* axis. The findings showed that lithium disilicate ceramic has superior color stability when compared to stained monolithic zirconia and monolithic zirconia in a zone of one MiYO layer has better color stability in comparison to a zone of two MiYO layers. Statistically, a significant difference in ΔE was observed after 1000 thermal cycles between stained monolithic zirconia and lithium disilicate ($P<0.05$), while after 2000 thermal cycles the differences were statistically insignificant ($P>0.05$). In addition, the differences in ΔE for two zones of monolithic zirconia in both thermocycling stages were statistically insignificant ($P>0.05$). These findings are in line with those of Kurt, et al. [25] and Haralur, et al. [26] who demonstrated that monolithic zirconia is more susceptible to aging-related color changes. In terms of color stability and translucency, they discovered that the lithium disilicate ceramic provides more esthetic compared to monolithic zirconia. Without a ceramic veneer to protect it, the monolithic zirconia is subject to water and bodily fluids inside the mouth. Low-temperature degradation (LTD) is caused by the phase transformation from a tetragonal to a monoclinic structure that occurs when water is exposed to a 37 °C environment [27]. Volume increased by 4% as a result of the phase transformation to monoclinic, which causes structural disintegration, surface roughness, and the formation of microcracks [28].

Unfortunately, limited published data is available for evaluating the effects of thermal aging on the color stability of externally stained ceramics. Metal oxides are added to the ceramic structure to get a desirable color, but upon heating, they change their color which affects the ceramics' esthetic. According to Lund and Piotrowski, et al. [29] and Crispin et al. [30] at various baking temperatures, yellow and orange stains have very little color stability. Furthermore, Mulla, et al. [31] showed that orange stain has the maximum color stability at various baking temperatures, whereas in ceramic systems the lowest color stability accounts for blue stain.

The recommended tooth preparation for monolithic zirconia crowns is 2 mm of occlusal clearance, according to the literature [32]. As in the studies by Hamza, et al. [33] and Koseoglu, et al. [34] after artificial aging, there was a color shift in the present study for 2 mm thickness monolithic zirconia that was below the clinically acceptable threshold.

In the present study, thermal cycling was used which is one of the processes used to try to imitate the physiological aging of restorative materials. The studies reveal that protocols and variables for thermal cycling procedures are inconsistent which makes comparing the findings of different studies challenging. Investigators appear to have chosen factors such as cycle count, transfer and dwell times in water baths based on convenience rather than scientifically based facts or cited observations [35,36]. In this study 1000 thermal cycles were conducted two times to imitate intra-oral environmental aging conditions as used by several studies [37–39]. The thermocycling parameters were determined by calculating that 1000 thermo cycles would simulate the environment in the oral cavity for one year [37,40].

One of the study's limitations was the use of thermocycling alone for aging the samples to simulate intraoral conditions; this method does not accurately reproduce the intraoral environment to which restorative materials are subjected because, in addition to thermal stimuli, the restorative materials in the mouth are also affected by mechanical and chemical stimuli. Another limitation was using only 2000 thermal cycles to evaluate the color change of ceramics. A further study using longer thermal aging in addition to other factors is recommended to evaluate the MiYO esthetic system.

CONCLUSION

In conclusion, within the limitation of this in vitro study the findings showed that the color stability of monolithic zirconia stained MiYO esthetic system and lithium disilicate ceramic was within the clinically acceptable range after thermal aging but can be perceptible by the naked eyes. After 1000 thermal cycles the lithium disilicate had superior stability of color than MiYO stained monolithic zirconia while no significant difference was observed between them after 2000 thermal cycles. In addition, there was no significant difference in color stability between MiYO stained monolithic zirconia at the zone of one MiYO layer and a zone of two MiYO layers. Hence the MiYO stained monolithic zirconia is a good alternative to lithium disilicate ceramic restorations in the esthetic zone when higher mechanical properties are required and the patient can't afford the higher cost of lithium disilicate restoration. Further studies are recommended to evaluate the MiYO esthetic system by using chemical and mechanical stimuli as well as longer thermal aging.

DATA AVAILABILITY

The data used to support the findings of this study are available with the corresponding author upon reasonable request.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest relevant to this article.

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