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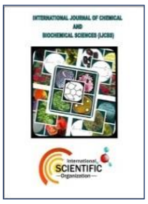

Optical properties of monolithic color-gradient zirconia and lithium disilicate glass-ceramics: A comparitive in-vitro study

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Abstract

The goal of this study is to compare the optical characteristics during thermocyclic ageing of a novel zirconia ceramic (IPS e.max ZirCAD prime) against a lithium disilicate glass ceramic (IPS e.max CAD). Specifically, color stability and translucency are the focus of this analysis . In accordance with the kind of ceramic, forty specimens (10 mm x 10 mm x 0.5 mm) were created and split into two groups of twenty. In order to conduct color and translucency tests, each group was further split into two subgroups of ten. Finally, each sub-group was exposed to 5,000 thermal aging cycles in a thermocycler. Using a spectrophotometer, values for the color difference and translucency parameter were obtained. There was no significant difference between the ceramics based on the mean ± SD values for color stability of IPS e.max ZirCAD prime and IPS e.max CAD, which were 6.01 ± 2.33 and 7 ± 2.66, respectively. For IPS e.max ZirCAD prime, the mean ± SD translucency parameter values were 14.93 ± 3.41 and 18.44 ± 2.99, and for IPS e.max CAD, they were 25.18 ± 2.23 and 24.25 ± 4.94, respectively, before and after ageing. The translucency of both ceramics was not significantly affected by thermocycling. But both before and after ageing, IPS e.max ZirCAD prime had noticeably less translucency than IPS e.max CAD. Color stability was similar for IPS e.max CAD and IPS e.max ZirCAD prime. The translucency of both ceramics was unaffected by thermocyclic ageing. But both before and after ageing, IPS e.max ZirCAD prime had substantially less intrinsic translucency than IPS e.max CAD.

Keywords: Aging, Color, Glass ceramic, Monolithic zirconia, Translucency.

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1. Introduction

Ceramic restorations, such zirconia and lithium disilicate, are becoming more and more common as dental treatments that provide maximum biocompatibility and a flawless appearance become more and more in demand [1,2]. When it comes to making monolithic restorations, lithium disilicate ceramics (LDC) show great promise. These restorations have exceptional flexural strength, enhanced translucency, and outstanding aesthetics since they are composed of lithium oxide (Li2O) with a silica glass matrix. They can be used to single crowns, inlays, onlays, veneers, and three-unit anterior fixed partial dentures, among other dental uses [3]. Lithium disilicate also has benefits such decreased porosity and improved marginal integrity [4]. Zirconia stands out as one of the tooth-colored materials, boasting numerous advantages such as appealing esthetic characteristics, exceptional mechanical properties, and optimal biological behavior, making it suitable for a variety of complex clinical situations. However, the opaque appearance of zirconia can negatively impact esthetic outcomes. To address this, layering materials were suggested to conceal this appearance, but issues such as porcelain chipping in veneered zirconia crowns have been reported as a common problem [5]. In response to the delamination challenges faced by previous zirconia-based restorations, innovative Monolithic generations have been developed [6]. Zirconia has less translucency than other ceramic materials because of its strong crystalline structure and absence of a glassy matrix. Numerous elements, such as zirconia's density, sintering conditions, chemical composition, additives, and structural features, affect the material's translucency. Furthermore, the discontinuity of the refractive index at the grain boundary causes birefringence because of the distinct crystallographic orientation of the grains. An increase in the yttria concentration results in both an increase in the optically isotropic cubic phase and bigger grain sizes. Birefringence is not produced by the cubic phase, in contrast to other crystallographic phases. Additionally, cubic grains are more resistant to low temperature degradation since they do not change at room temperature. Because the alumina dopant has a different refractive index than alumina, it adds to the opacity of zirconia. Various methods can be employed to enhance the optical performance of Y-TZP, including modifying its microstructure, increasing the yttria percentage, reducing the alumina dopant, adjusting the sintering parameters, reducing residual porosity, and establishing a nanometric microstructure [7-9].

The latest iteration of zirconia restorative material, IPS-e.max® ZirCAD® Prime, represents the cutting edge in the evolution of all-ceramic restorations. This innovative material introduces the concept of constructing zirconia blanks with layers featuring varying translucencies and shades, ensuring exceptional quality in both aesthetics and mechanical properties. The distinctive "gradient technology" (GT) enables the combination of two zirconium oxide raw materials—3Y-TZP for strength and 5Y-TZP for aesthetics—within a single disc [10-12]. A key concern in color studies involves assessing color differences or changes. ΔE color difference formulas have been established based on differences in color coordinates between a restoration and a tooth/target or within an object before and after an experimental process. Various formulas for ΔE, such as ΔE_{ab} ($\Delta E_{ab} = [(L)^2 + (a)^2 + (b)2]^{1/2}$) and ΔE_{00}, have been utilized [10,13]. Translucency refers to the extent or degree to which light can pass through a material, and it plays a crucial role in the characteristics of all ceramic restorations. This phenomenon occurs when a light beam passes through an object, reflecting, scattering, and transmitting partially through it. The degree of translucency increases as more light passes through the object [8,12]. It's essential to note that optical properties, including color and translucency, along with chemical bonding, can undergo changes during cyclic expansion and contraction at high and low temperatures, a phenomenon known as aging. Therefore, in this study, the color stability and translucency parameter were evaluated both before and after aging procedures because aging can impact various properties of the restoration [12]. This study's main goal was to compare the optical characteristics of lithium disilicate glass ceramic (IPS e.max CAD HT) with a novel strength gradient zirconia ceramic (IPS e.max ZirCAD Prime), both before and after artificial ageing procedure. The study's null hypothesis suggested that the optical characteristics of the new gradient zirconia IPS e.max ZirCAD Prime and the IPS e.max CAD ceramic would demonstrate no difference.

2. Materials and methods

2.1 Study design

This study is an *in-vitro* study.

2.2 Materials

The materials utilized in this investigation include:

- one partially sintered disc of Monolithic Polychromatic gradient zirconia (IPS e.max ZirCAD Prime, Ivoclar, Schaan, Liechtenstein) (Incisal: 5Y-TZP Dentin: 3Y-TZP), Batch #:Z03VHG, shade: A2.
- Two partially sintered blocks of Lithium disilicate glass-ceramic (IPS e.max CAD HT, Ivoclar, Schaan, Liechtenstein), Batch #:Z01SBK . shade: A2.
-

2.3 Methods

A previous research [14] served as the basis for determining the present sample size. The study needed ten people in each group due to the control group's mean ± standard deviation of 9.26 ± 0.51 and the intervention group's anticipated mean of 10, an effect size of 1.45, a power of 0.8, and a Type I error probability of 0.05. An independent t-test with G. power 3.1.9.7 was used to calculate the sample size, yielding a total sample size of 10 people for each group.

2.4 Samples grouping

Forty specimens measuring 10 mm x 10 mm and 0.5 mm were fabricated and allocated for two optical properties tests. These samples were then categorized into two groups, comprising a total of 20 samples, based on the type of ceramic being examined. Each group was then split into two subgroups based on the particular test that they would be put through, with each subgroup having ten samples (Color test or Translucency test). Lastly, each subgroup was subdivided into two classes, representing the conditions before and after the aging process.

2.5 Specimens' preparation

2.5.1 Preparation of the IPS e.max samples

Discs measuring 10 mm x 10 mm x 0.5 mm were created using blocks of IPS e.max CAD HT. Diamond slices with a thickness of 0.6 mm were cut at a cutting speed of 2500 rpm using an IsoMet 4000 micro-saw, which was equipped with a cooling water system Fig. 1. Subsequently, each ceramic slice underwent examination using a digital caliper. The crystallization process was carried out in a compatible ceramic furnace, the Programat P310 ceramic furnace. All samples were subjected to crystallization following the firing parameters stipulated by the manufacturer, involving tempering at 850 °C for 25 min under vacuum.

2.5.2 Preparation of the Zirconia specimens

The same procedure but using IPS e.max ZirCAD prime discs. With the following dimensions: 12 mm x 12 mm x 0.6 mm. Fig. 2. To compensate for zirconia shrinkage and distortion, the specimens were made slightly larger by 20% than the desired size. These specimens were then fired at 1500C (Programat S1 1600 118-240V/50-60Hz, ivoclar, vivadent) in accordance with the manufacturer's instructions.

2.6 Thermocycling

Five thousand thermocycling cycles were applied to the specimens in order to mimic the mouth cavity's environment (SD-Mechatronik, Westerham, Germany). The dwell and lag times for each water bath were 25 and 10 seconds, respectively. Two temperature extremes were observed: a low of 5°C and a high of 55°C [15].

2.7 Measuring Optical properties before and after artificial aging

2.7.1 Color parameter measurement

Using a spectrophotometer, the original color characteristics (hue, value, and chroma) of each sample were determined prior to ageing. Three parameters—a, b, and L—were used to record color in the CIELAB color space where these values were stated. In particular, detects positive redness and negative greenness; b detects positive yellowness, neutrality, and negative blueness; L detects lightness; 100 denotes white, and 0 black. Color measurement of the specimens was conducted both before and after 5000 thermo-cycles, using a spectrophotometer to ascertain the changes in color content. The overall color difference between the samples before and after aging was calculated as ΔE using the equation [12,16]: $\Delta Eab = ([\Delta L^*]^2 + [\Delta a^*]^2 + [\Delta b^*]^2)^{1/2}$, where ΔL = L before aging – L after aging, Δb =

b before aging – b after aging, and Δa = a before aging – a after aging.

2.7.2 Measuring translucency parameter

The translucency parameter for all the samples, baseline and after aging, was assessed using a spectrophotometer. The device was employed in accordance with the CIE L*a*b* color scale relative to the CIE standard illuminant D65, corresponding to average daylight as defined by the International Commission on Illumination. The translucency parameter was determined by calculating the color difference of the sample over white and black backgrounds using the following equation [8,13]:
(Tp= {(Lb*-Lw*)² +(ab*aw*)² +(bb*bw*)² } ½).
In this equation, L* denotes lightness, a* represents redness to greenness, and b* indicates yellowness to blueness.

2.8 statistical analysis

Utilizing SPSS 16 ® (Statistical Package for Scientific Studies, IBM Corp, Armonk, NY), Graph Pad Prism (RITME, Paris, France), and Windows Excel, the statistical analysis was carried out and the results were displayed in two tables and one graph. The Shapiro-Wilk and Kolmogorov-Smirnov tests were used to explore the provided data for normality, and the results showed that the data came from a normal distribution. As a consequence, the independent t test was used to compare the two groups, and the paired t test was used to compare the ageing outcomes before and after.

3. Results

3.1 Color changes

A comparison between Zirconia ceramic (IPS e.max ZirCAD Prime) and Lithium disilicate ceramic (IPS e.max CAD) revealed no significant difference between the two groups, with a p-value of 0.39, as presented in Table. 1 and Fig. 3.

3.2 Translucency

3.2.1 Effect of thermocycling on translucency (comparison between before and after thermocycling procedure)

A comparison between before and after aging in both Zirconia ceramic (IPS e.max ZirCAD Prime) and Lithium disilicate ceramic (IPS e.max CAD) was carried out to assess the impact of thermocycling which revealed no significant difference between them in both groups, with p-values ≥ 0.05, as presented in Table. 1 and Fig. 3.

3.2.2 Effect of material on translucency (comparison between IPS e.max ZirCAD Prime and IPS e.max CAD):

A comparison between Zirconia ceramic (IPS e.max ZirCAD Prime) and Lithium disilicate ceramic (IPS e.max CAD) to assess the impact of thermocycling was performed and demonstrated that: Before aging, Zirconia ceramic (14.93 ± 3.41) showed a significantly lower translucency compared to Lithium disilicate ceramic (25.18 ± 2.23), with a mean difference of (10.25), and a p-value of 0.0001. While after aging, zirconia ceramic (18.44 ± 2.99) demonstrated a significantly lower translucency than lithium disilicate ceramic (24.25 ± 4.94), with a mean difference of (5.8), and a p-value of 0.005, as presented in Table. 1 and Fig. 3.

3.2.3 Comparison between different variable effect on translucency parameter

The impact of all variables on translucency parameter was assessed through a Two-Way ANOVA test. The results indicated that the material had a significant effect, while thermocycling had an insignificant effect, as presented in Table. 2.

4. Discussion

The standard measurement tool used in this work to quantify color coordinates, color changes, and the translucency parameter was a spectrophotometer [17, 18]. According to Sulaiman et al. [19], the translucency parameter for each sample was obtained by dividing the sample findings against white and black backings by TP= $\{(Lb^*- Lw)^2 + (ab^* - aw^*)^2 + (bb^* - bw^*)^2\}^{1/2}$.
There are several benefits to using the CIE L*a*b* system in spectrophotometric analysis, one of which is the capacity to identify color shifts that would not be apparent to the naked eye [20]. To encompass a wide range of materials used in esthetic dentistry and ensure uniformity and consistency, this study employed two monolithic ceramic materials. Ceramic samples were crafted from IPS e.max ZirCAD Prime discs and IPS e.max CAD HT blocks, both with a shade of A2, a thickness of 0.5 mm, and a width of 10 mm. In this study, IPS e.max CAD glass-ceramic was chosen due to its frequent use as a ceramic material known for providing optimal esthetic characteristics, including sufficient light transmission, high translucency, and a natural resemblance to the teeth [3,21,22]. The innovative strength gradient IPS e.max ZirCAD Prime zirconia ceramic has been introduced, featuring a unique multilayered technique that combines various zirconia generations within a single blank. This approach aims to offer the advantages of both traditional and ultra-translucent ceramics [14]. For cautious preparations, sample preparations were standardized at 0.5 mm in thickness. permitting more light to pass through the thin layer of transparent ceramic, which raises the degree of conversion of the resin cement underneath [23]. Understanding that restorations could face difficulties in a humid and thermally dynamic oral environment [24], a thermocycling technique was used to apply an aging regimen to every specimen in this investigation. Six months of in vivo function were simulated with 5000 heat cycles [15,25]. In this investigation, the samples were precisely cut using the IsoMet 4000 micro saw, a well-established method widely used in research [26,27]. This method is preferred for its minimal sample mutilation and lower kerf loss, ensuring a systematic thickness throughout the study [28]. Following the approach suggested by Sherif et al. [29], discs were prepared using the IsoMet microsaw 4000, and to account for sintering shrinkage, the zirconia samples were milled 20% larger than the required dimensions [30]. When IPS e.max CAD and IPS e.max ZirCAD Prime ceramics were compared, the study's findings about the influence of material on color shifts showed no discernible difference between the two groups. Consequently, this aspect of the null hypothesis was accepted. Zirconia exhibited a relatively lower ΔE due to an increase in yttria content, achieving electrical neutrality through the creation of O2 vacancies that stabilizes in the cubic phase; a phase less susceptible to aging [31].

Fig. 1

Figure 1: Photograph showing IPS e.max CAD blocks being cut into slices using Iso Met 4000.

Fig. 2

Figure 2: Photograph showing IPS e.max ZirCAD prime disc being crafted using IsoMet 4000.

Fig. 3

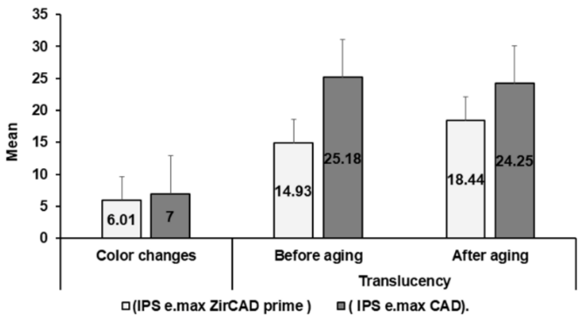

Figure 3: Bar chart representing color changes, translucency before and after thermocycling in both groups.

Table 1: Mean and standard deviation of color changes, translucency before and after aging in both groups and comparison between them.

		(IPS e.max ZirCAD prime)		(IPS e.max CAD)		Difference (Independent t test)				
		M	SD	M	SD	MD	SED	95% CI L	95% CI U	P value
Color changes		6.01	2.33	7	2.66	0.99	1.12	-1.36	3.34	0.39ns
Translucency	Before aging	14.93	3.41	25.18	2.23	10.25	1.29	7.54	12.96	0.0001*
	After aging	18.44	2.99	24.25	4.94	5.8	1.83	1.97	9.64	0.005*
P value		0.68ns		0.11ns						

M: mean SD: standard deviation MD: mean difference SEM: standard error mean
CI: confidence interval L: lower arm U: upper arm
*Significant difference as P<0.05
Ns: non-significant difference as P>0.05.

Table 2: Evaluation of two variables effect on translucency using Two Way ANOVA test.

ANOVA table	SS	MS	P value
Thermocycling effect	16.57	16.57	0.4002 ns
Material effect	644.6	644.6	<0.0001*

*Significant difference as P<0.05
Ns: non-significant difference as P>0.05.

The microstructural changes in the novel generations of zirconia ceramic, accompanied by a decrease in surface roughness and increased light scattering and reflection, resulted in higher color stability, as reported by Lucas et al. [32]. The study's findings align with Mezeid et al. [33], Ashy et al. [34], and Subaci et al. [35], who reported no significant difference in color change values after the aging procedure among various CAD-CAM monolithic ceramic materials. Regarding the impact of thermocycling on the translucency parameter, the results indicated no statistically significant difference between IPS e.max and IPS ZirCAD Prime after artificial aging. Therefore, this aspect of the null hypothesis was not rejected. These results, in line with Ahmed et al. [36], were attributed to the substantial amount of cubic phase, allowing zirconia to be hydrothermally stable. This stability is associated with a decrease in superficial irregularity, light scattering, and reflection [32], an interpretation consistent with a study by Volpato et al [37]. The results of this investigation were somehow consistent with those of Kanpalta et al. [38]. According to their findings, following artificial aging, the total translucency parameter (TP) of monolithic zirconia rose, while there was no statistically significant variation in that of lithium disilicate specimens. In contrast, Al-saffar et al. [39] reached a different conclusion, asserting that hydrothermal aging led to a decrease in TP for both IPS ZirCAD Prime and IPS e.max. The suggested explanation for the decline in translucency for ZirCAD Prime (3Y-TZP/5Y-TZP), was that aging induced a generalized irregular surface with micro-retentive areas, acting as porosity spots that scatter light, thereby reducing translucency. For lithium disilicate, selective ion leaching induced porosity, resulting in lower translucency. Another explanation proposed by Qassim and Hassan [40] who suggested that water vapor would attack the Zr–O bonds, breaking them down and causing stress concentration due to OH movement. This process would generate lattice defects, acting as nucleating agents to stimulate tetragonal to monoclinic phase (t–m) transformation [41,42]. The results of this study showed that, with regard to the influence of ceramic type (aged and non-aged specimens) on the translucency parameter, lithium disilicate (IPS e.max CAD) had a translucency parameter that was significantly higher than that of the novel strength-gradient zirconia (IPS ZirCAD Prime) both before and after artificial ageing. Consequently, this aspect of the null hypothesis was rejected. This finding was consistent with several studies conducted by Al-saffar et al. [39] and Ziyad et al. [43], emphasizing the nature of lithium disilicate, which comprises spindle-shaped crystals with nearly the same refractive index as the glassy matrix in which they are embedded. In contrast, zirconia is inherently opaque due to the size of the crystalline particles, leading to increased light scattering and lower translucency. A study by Michalova et al. [14], examining the optical properties of Katana zirconia and IPS e.max ZirCAD Prime, and comparing them to IPS e.max CAD under aging conditions, reported similar results to the current study. This observation has also been validated in other studies [44,45]. Further investigations should be undertaken to explore the optical properties of novel highly translucent ceramic materials to delineate their recommended clinical applications.

5. Conclusion

Given the constraints associated with this *in vitro* investigation, the ensuing deductions may be made: Thermocycling did not affect the translucency of the specimens. The novel monolithic zirconia ceramic showed noticeably lower values than lithium disilicate glass-ceramic, pre and post-aging protocol. Following artificial aging, the color stability of monolithic zirconia ceramic and high-translucency monolithic lithium disilicate glass-ceramic was equivalent at a restoration thickness of 0.5 mm.

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Conflict of Interest

The authors declare that they have no personal financial, proprietary, or other interests of any sort in any of the goods, services, or businesses mentioned in this article.

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