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COLOR STABILITY OF A NEW ESTHETIC ZIRCONIA WITH GRADIENT
TECHNOLOGY

by

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DEDICATION

To my dearest wife Vanessa and our children all of whom make this life

- Phillip A. Jenkins

DISCLAIMER

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ABSTRACT

COLOR STABILITY OF A NEW ESTHETIC ZIRCONIA WITH GRADIENT TECHNOLOGY

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Thesis directed by: CDR Nicholas Hamlin, Professor, Research Department

Introduction: Ivoclar recently introduced IPS e.max ZirCAD Prime® with a gradient shade technology. The color stability of this new zirconia has not been thoroughly investigated. **Objective:** The purpose of this study was to investigate the color stability of IPS e.max ZirCAD Prime as compared to IPS e.max CAD lithium disilicate. **Methods:** 1mm thick × 10mm square samples of each material were prepared; ZirCAD Prime had 15 samples from each zone and 30 for lithium disilicate. Samples were thermocycled 20,000 times between 5°C and 55°C to simulate 2 years of use. Color change was determined by calculating ΔE at each 5,000 cycle interval across groups. **Results:** Statistically significant change in the incisal zone with an average ΔE of 1.6. **Conclusions:** Under the thermocycling conditions employed in this study, IPS e.max ZirCAD Prime was found to be color stable in the middle and dentin zones and statistically unstable in the incisal zone.

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LIST OF ABBREVIATIONS

CAD	Computer Aided Design
CIE	Commission Internationale de l'Eclairage
e.max	esthetic maximum
IPS	Ivoclar Porcelain Systems
L*a*b*	L*-lightness, a*-green to red, b*-blue to yellow
ZirCAD	Zirconia Computer Aided Design

CHAPTER 1: Introduction

The increased use of all ceramic restorations in the esthetic zone has led to an ever-increasing desire for translucency. Lithium disilicate restorations nearly mimic the translucency properties of enamel and dentin whereas traditional zirconia restorations fall short.¹ Porcelain veneered zirconia tries to take advantage of the physical properties of zirconia while applying the esthetic properties of porcelain, unfortunately there is a 15% complication rate.² Porcelain fracture (chipping) is the most common issue with the occasional zirconia framework fractures.

Attempts have been made to close the translucency gap between lithium disilicate and zirconia. The conventional monolithic (1st generation) zirconia is exceptionally opaque.^{1,3} The second generation made a step towards more translucency, but the third generation made a bigger stride. The trade-off for the increased translucency was a decrease in strength from the first generation of 1200MPa down to 600Mpa in the third generation.⁴ The increase in translucency was accomplished by adding more yttrium oxide. Still the advancement has only produced results approaching the translucency of lithium disilicate low translucency.⁴ Katana Ultra Translucent has been reported to have the highest translucency of all zirconia⁵, yet lithium disilicate still has a clear advantage in translucency. Particle size and sintering temperatures can also affect the final translucency of zirconia.^{6,7}

The color properties of monolithic zirconia have been investigated, but the newer materials have not been evaluated.^{8,9} The optical properties of various resin-ceramic polymer-based materials have been shown to degrade under ultraviolet light aging.¹⁰ The optical stability of monolithic zirconia has been shown to degrade during cyclic loading.¹¹ There are various methods to evaluate the color properties of a given material including colorimeters,

spectrophotometers, digital cameras, and visual shade selection.¹² The most common in dentistry is visual shade selection, but that method is fraught with bias.¹³ The VITA Easyshade Advance V allows for an impartial assessment of the Commission Internationale de l'Eclairage (CIE) L*a*b* values (L*-lightness, a*-green to red, b*-blue to yellow).

Ivoclar has recently released a new zirconia (ZirCAD Prime) with a gradient technology rather than the previous distinct multi-layer version with an incisal, middle, and dentin zone. The reported strength ranges from 650Mpa to 1200Mpa from incisal to dentin zones respectively. The question is the color stability of the new zirconia. There are two null hypotheses of this study: 1) the color properties CIE L*a*b* values of IPS e.max ZirCAD Prime and IPS e.max CAD lithium disilicate will not change with thermal cycling. 2) With respect to color stability, both IPS e.max ZirCAD Prime and IPS e.max CAD lithium disilicate will tolerate thermocycling to an equal degree.

CHAPTER 2: Materials and methods

IPS e.max ZirCAD Prime samples 1.0 ± 0.05 mm thick and a square of 10mm from each of the three color gradients (incisal, middle, dentin) were milled. Shade A2 was utilized for this study. IPS e.max CAD lithium disilicate samples of the same dimensions of shade A2 low translucency served as a control. Each milled sample was sintered or crystalized according to manufacturer's recommendations.

Lithium disilicate samples were nested using inLab CAM software (Dentsply Sirona, Charlotte, NC) with block C14 shade A2 low translucency positioned to fit two samples per block. Milling was completed with MCXL wet milling using 12s step and cylinder pointed 12s burs. Samples were desprued and crystalized using Ivoclar Vivadent Programet P510 at 850 degrees Celsius for 10 minutes as per manufacturer's instructions.

Zircad prime samples were nested using hyperDENT software (Follow-me! Technology, Milford, NH) and dry milled on a 150i five axis mill (imes-icore GmbH, Eiterfeld, Germany) using carbide burs. Zircad Prime pucks were measured to be between 20.02-20.07mm in thickness. Nesting position for the upper and lower samples was set as close to the top or bottom as possible allowing for a 1.5mm sprue. Middle samples were nested directly in the middle of the puck (10mm). Samples were sintered in a Programat S1 1600 furnace (Ivoclar Vivadent, Amherst, NY), using software version V 6.0; program 1 IPS e.max ZirCAD standard for 9 hours and 50 minutes.

To ensure proper thickness, the samples were verified to be within range of 1.0 ± 0.05 mm with a caliper manufactured by Mitutoyo.

Samples were thermocycled 20,000 times with temperatures from 5°C to 55°C and a 60-second dwell time to simulate approximately 2 years of use.¹⁴ CIE L*a*b* values were recorded

every 5,000 cycles utilizing VITA Easyshade Advance V (VITA North America, Yorba Linda, CA) with three consecutive measurements. The averages were recorded.

Color change due to the cyclic loading was calculated for each specimen as a linear distance in 3D color space: $\Delta E = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$.¹⁵ Color changes of $\Delta E < 1$ are considered to match. Values between 1 and 3.3 are deemed different, although not clinically relevant. Values greater than 3.3 were deemed to not match and thus unacceptable even by the untrained eye.¹¹

CHAPTER 3: Results

Figure 5 shows the ΔE from each 5,000-cycle interval. The greatest variation existed in the middle group of the zirconia puck. Figure 4 gives a box and whisker plot of the final ΔE . The variation that existed in Figure 5 of the middle group can be explained by three distinct outliers. Once excluded, the ΔE of the bottom and middle samples of zirconia are clearly more similar than the other two samples. The variation of ΔE in both the top zirconia and lithium disilicate groups are clearly larger than the bottom and middle groups. Once this is delineated, the picture becomes clearer that the true variation exists in the incisal zone of the zirconia and the lithium disilicate groups. ΔE for baseline versus 20,000 cycles was higher in the incisal versus dentin ($p < 0.01$) and in the incisal versus middle ($p = 0.01$) groups. Higher ΔE in the incisal versus lithium disilicate group approached significance ($p = 0.10$). P values are from pairwise comparisons using Wilcoxon tests with p values adjusted for multiple comparisons using the Bonferroni method.

CHAPTER 4: Discussion

The linear distance in color space is composed of a scale from 0 to 100. No appreciable color change is indicated by a value of 0 to 1. An absolute match would be indicated by a ΔE of 0. Any value greater than 0 up to 1, although different, would be considered statistically a color match. A value ranging from 1 to 3.3 would indicate a statistically significant finding but be considered clinically irrelevant. Any value extending from 3.3 to 100 would be easily discernable even by the untrained eye. A value of 100 indicates two completely opposite colors.

The baseline $L^*a^*b^*$ values are listed in Figures 1, 2, and 3 respectfully. The greatest variance is in the b^* values with a standard deviation of 1.10 throughout all zirconia and lithium disilicate samples. Each graph's y-axis is on a different scale, which makes the L^* values appear to have a greater standard deviation, but after a closer inspection of Table 1, it is clear that the greater deviation is found in the b^* value. Linear distance in color space, which was measured by ΔE , varied the greatest amount in each sample from the initial reading to the reading at 5,000 cycles. An interesting finding in figure 5 is that no distinct linear or exponential pattern was found from one cycle to the next. This might be indicative of the nature of 3-dimensional color space in that change may happen in an oscillating format rather than from a direct path of lightness to darkness or one color to another.

Three-dimensional color change was found to be minimal for three of the four sample at the end of 20,000 cycles as indicated in Figure 4. The dentin, middle, and lithium disilicate samples were found to exhibit no statistically significant change over the course of two years' worth of simulated thermal aging. The only sample to end the study with a value of statistical significance was the incisal sample with a ΔE of 1.6. The rub is that the incisal sample was not statistically different from the lithium disilicate sample and since that sample was deemed to be

under 1 for ΔE , it cannot be conclusively deduced that the incisal sample was different even when limited to a statistical significance. No samples, excluding a few outliers, ever approached clinical significance.

Table 1 includes the averages of each of the samples from baseline throughout the ΔE 's from each cycle. Care must be taken when evaluating the right column of the table which includes a summary of all values. For instance, in the baseline b^* value, the right column has a standard deviation of 8.68 due to the fact that the incisal layer has a different blue to yellow content compared to the other samples. The standard deviation for each of the other columns approximate 1. The standard deviation of the other average values mimics the individual samples. This indicates that the main color difference between the gradient of the ZirCAD Prime comes primarily from the blue to yellow portion of the three-dimensional color space and not from the lightness nor from the red to green portion. This is indeed interesting in that it may be assumed that more lightness would be required for the incisal zone, but the greater change is that from the blue to yellow component.

The primary objective was to evaluate thermal aging. Limitations of this study include that the study does not account for other factors such as varying pH levels, cyclic loading, toothbrush abrasion, possible bruxism, or ultraviolet radiation.

CHAPTER 5: Conclusions

The incisal zone of ZirCAD Prime is color-unstable statistically with a ΔE of 1.6, although this finding was statistically similar ($p=0.10$) to the change observed in the control material, lithium disilicate over the same 20,000 cycles of simulated aging. The dentin and middle sections were found to be color stable. Overall, the newer zirconia gradient of ZirCAD Prime was found to be clinically color stable under these *in vitro* conditions compared to both the baseline and the control.

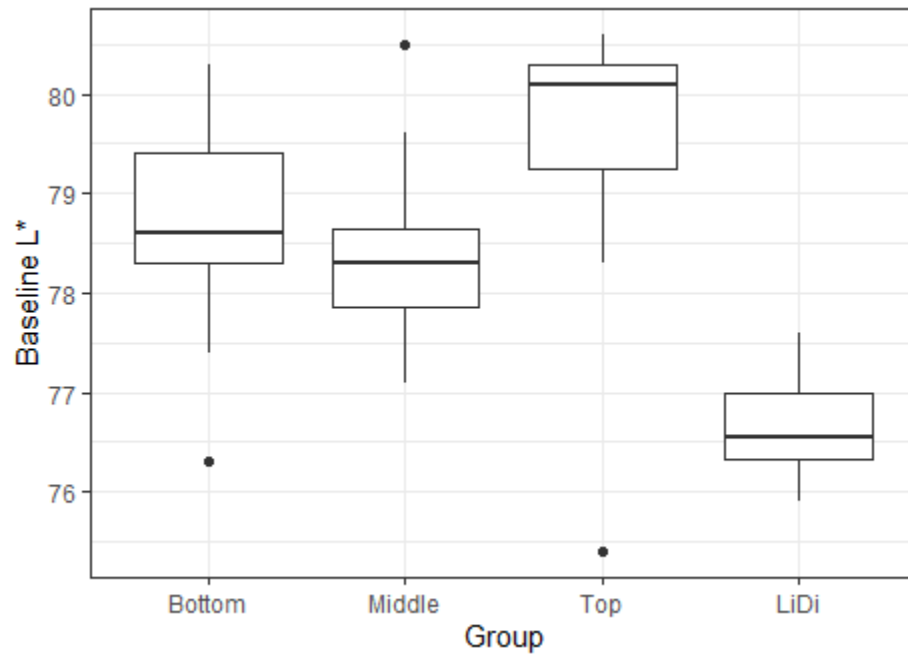


Figure 1. Baseline L* values for each of the four groups.

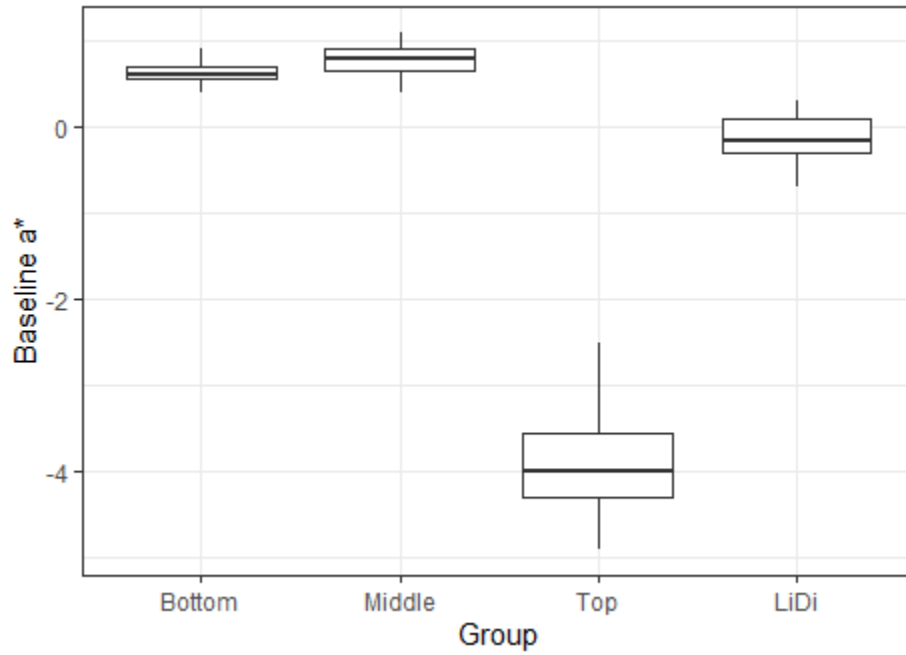


Figure 2. Baseline a* values for each of the four groups.

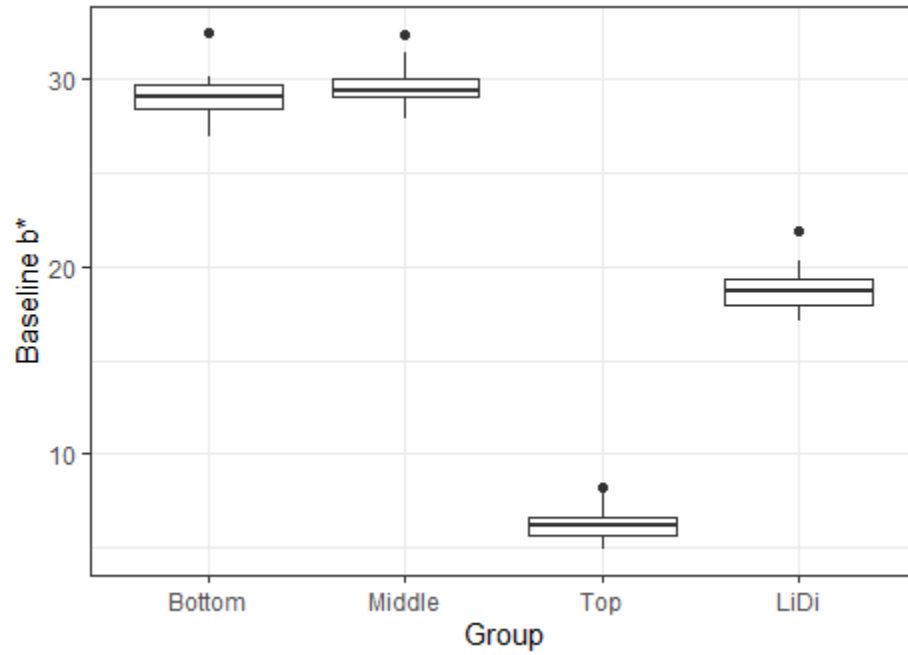


Figure 3. Baseline b^* values for each of the four groups.

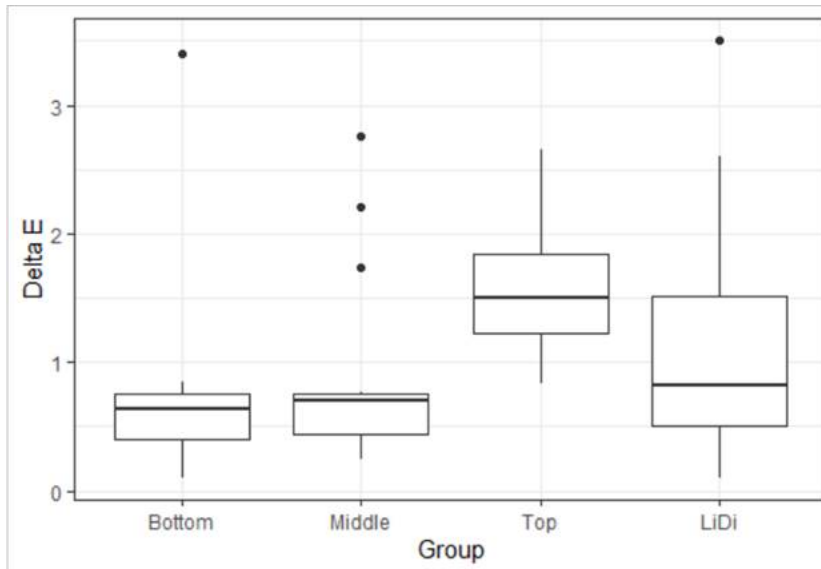


Figure 4. Delta E values for each of the four groups.

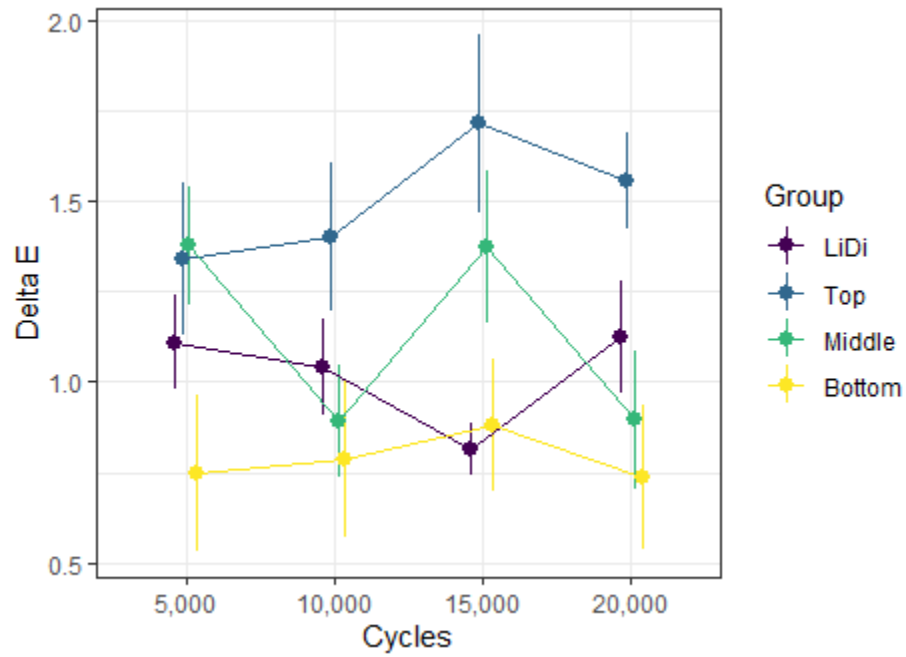


Figure 5. Delta E values for each of the groups at 5,000 up to 20,000 cycles.

Table 1. Each of the four sample groups listed across the top with the baseline values listed As the first three values followed by delta E values from 5,000 cycles up to 20,000 cycles.

	LiDi (N=30)	Top (N=15)	Middle (N=15)	Bottom (N=15)	All (N=75)
Baseline L*					
Mean (SD)	76.7 (0.44)	79.6 (1.35)	78.4 (0.86)	78.7 (1.03)	78.0 (1.44)
Median [Min, Max]	76.6 [75.9, 77.6]	80.1 [75.4, 80.6]	78.3 [77.1, 80.5]	78.6 [76.3, 80.3]	77.9 [75.4, 80.6]
Baseline a*					
Mean (SD)	-0.14 (0.29)	-3.88 (0.64)	0.77 (0.21)	0.63 (0.14)	-0.55 (1.75)
Median [Min, Max]	-0.15 [-0.70, 0.30]	-4.00 [-4.90, -2.50]	0.80 [0.40, 1.10]	0.60 [0.40, 0.90]	0.10 [-4.90, 1.10]
Baseline b*					
Mean (SD)	18.8 (1.02)	6.29 (0.94)	29.6 (1.15)	29.1 (1.28)	20.5 (8.68)
Median [Min, Max]	18.7 [17.1, 21.9]	6.20 [4.90, 8.20]	29.4 [27.9, 32.4]	29.1 [26.9, 32.5]	19.4 [4.90, 32.5]
Delta E - 5,000 cycles					
Mean (SD)	1.11 (0.71)	1.34 (0.82)	1.38 (0.63)	0.75 (0.84)	1.14 (0.76)
Median [Min, Max]	1.04 [0.10, 3.60]	0.99 [0.41, 2.51]	1.42 [0.57, 2.72]	0.40 [0.17, 3.40]	1.00 [0.10, 3.60]
Delta E - 10,000 cycles					
Mean (SD)	1.04 (0.73)	1.40 (0.79)	0.89 (0.60)	0.79 (0.83)	1.03 (0.75)
Median [Min, Max]	0.85 [0.10, 3.21]	1.21 [0.33, 2.91]	0.58 [0.30, 2.02]	0.41 [0.17, 3.40]	0.81 [0.10, 3.40]
Delta E - 15,000 cycles					
Mean (SD)	0.82 (0.39)	1.71 (1.00)	1.37 (0.81)	0.88 (0.71)	1.12 (0.77)
Median [Min, Max]	0.71 [0.20, 2.04]	1.72 [0.10, 3.52]	1.37 [0.20, 2.68]	0.73 [0.17, 3.01]	0.86 [0.10, 3.52]
Delta E - 20,000 cycles					
Mean (SD)	1.12 (0.86)	1.55 (0.51)	0.90 (0.74)	0.73 (0.77)	1.09 (0.79)
Median [Min, Max]	0.82 [0.10, 3.51]	1.50 [0.84, 2.65]	0.71 [0.25, 2.75]	0.64 [0.10, 3.40]	0.78 [0.10, 3.51]
Delta E values represent change from baseline.					

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