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“Effect of anodized titanium abutments on the color of lithium disilicate crowns”

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Effect of anodized titanium abutments on the color of lithium disilicate crowns

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## **ABSTRACT**

**Statement of Problem:** The effect of the implant abutment color on the shade of an all-ceramic restoration has been well researched. On the other hand, the difference in how the color of the abutment may affect the perceived color of the all-ceramic crowns of the 16 Vita classical shades is unknown.

**Purpose:** The objective of this study was to determine the effect that titanium abutments anodized in a wide range of colors have on the final shade of high translucency lithium disilicate crowns of the 16 Vita classical shades.

**Material and Methods:** High translucency lithium disilicate ingots of all 16 Vita classical shades were used to cut a single 1 mm thick disk from each ingot using a precision saw. A one-half inch diameter titanium rod was cut into thirteen 5 mm thick disks. The titanium disks were air-abraded and then anodized at every 10 volts from 0 to 120 volts to generate disks of thirteen different colors. A spectrophotometer was used to measure the actual shade of each lithium disilicate disk, using as background a lithium disilicate ingot of the same shade, to serve as control. The spectrophotometer was then used to measure the  $\Delta E$  between the shades of each lithium disilicate disk against each color-anodized titanium disk. A thin disk of resin-modified glass ionomer cement was interposed between the lithium disilicate and titanium disks to simulate a layer of cement. A 2-way ANOVA was performed to assess the effect of the color of the anodized titanium on the lithium disilicate disks of all 16 Vita classical shades.

**Results:** The mean  $\Delta E$  at 0V of anodization was, 1.87. The mean  $\Delta E$  at 10V of anodization was, 2.17. The mean  $\Delta E$  at 20V of anodization was, 2.57. The mean  $\Delta E$  at 30V of anodization was, 2.58. The mean  $\Delta E$  at 40V of anodization was, 2.0. The mean  $\Delta E$  at 50V of anodization was, 1.63. The mean  $\Delta E$  at 60V of anodization was, 1.50. The mean  $\Delta E$  at 70V of anodization was, 1.63. The mean  $\Delta E$  at 80V of anodization was, 2.15. The mean  $\Delta E$  at 90V of anodization was, 2.46. The mean  $\Delta E$  at 100V of anodization was, 2.23. The mean  $\Delta E$  at 110V of anodization was, 2.14. The mean  $\Delta E$  at 120V of anodization was, 2.1. The 2 way ANOVA of  $\Delta E$  measurements at various voltages revealed a statistically significant effect ( $p < 0.0001$ ) across all shades of the lithium disilicate disks.

**Conclusions:** The spectrophotometer readings amongst the 16 shades showed a biphasic pattern with the greatest  $\Delta E$  changes occurring at 20 - 30V and 90V. The least amount of  $\Delta E$  change was seen on the titanium disks anodized at 60V (yellow) and 70V (pink). The 2-way ANOVA indicated that anodized titanium disks of all colors exhibited a significant effect on the shade of the 1 mm high translucency lithium disilicate disks. Further statistical analysis of the  $\Delta L$  values indicated a decrease in value of all specimens tested with the greatest effect seen at 20V and 90V, both of which were dark purple in color.

## **CLINICAL IMPLICATIONS**

Dentists need to be aware of the significant difference that the implant abutment color can have on the shade of the final restoration. If a significant difference is not seen on the color of the crown material against a 60V or 70V (gold and pink, respectively) anodized titanium disk, a pink anodized abutment may be favorable for the color of the surrounding soft tissue. A difference in shade was determined for high translucency lithium disilicate crowns placed upon titanium

abutments of various colors. A consideration should be given to anodization of titanium abutments in cases of the esthetic zone and/or patients with a thinner tissue biotype.

## **INTRODUCTION**

Dental implants are now used routinely to restore not only posterior teeth, but anterior teeth alike. The American Academy of Implant Dentistry states that 500,000 new implants are being placed each year<sup>2</sup>. With an increasing number of patients requesting implants to restore their smile, it is imperative that the restorative dentist finds the right tools to deliver esthetically pleasing implant supported crowns.

One of the more challenging procedures we complete in dentistry is trying to match a restoration to the natural dentition. Matching the shade of the patient's natural teeth to the shade of an implant crown is a crucial requirement for an esthetic smile. Many implants are restored with a titanium abutment and an all-ceramic crown. This can lead to a significant color change in the crown due to the underlying silver color of the titanium abutment.

To accurately match a patient's tooth shade one must understand the basic elements of color. The three basic components of color are: hue (color), value (lightness or darkness), and chroma (intensity). These three components of color are the foundation of shade matching, but they are not all that is necessary in order to fabricate a natural-looking dental prosthesis. Another dimension of color that is critical to producing an esthetically acceptable restoration is translucency. It can be defined as the degree to which light is diffused as it passes through the restoration. Translucency is a principal factor in achieving esthetically pleasing ceramic restorations and it is important to mimic this property of natural teeth.<sup>4,5,21,22</sup>

In 1976, the Commission Internationale de l'Eclairage (CIE) developed the CIELab system, and after further research they published the CIEDE2000 system in 2001. These systems

allow us to express colors with numbers, which then we can calculate the difference between two colors.<sup>6,7</sup> Most electronic shade-taking devices use the  $\Delta E$  determined from the CIE formulas to quantify the color difference between a tooth and the chosen shade.

Ghinea et al. in 2010 found that the CIEDE2000 formula calculated a closer match than the CIELab formula in determining the color differences of dental ceramics. They also concluded that there was a statistically significant difference between perceptibility and acceptability thresholds for dental ceramics.<sup>8</sup> Other research by Wee et al in 2002 also supported the use of the CIEDE2000 formula because it provided a better fit to the calculated color differences. This is a better indicator of the perceptibility and acceptability of color variances between teeth.<sup>9</sup> In 2016, Gomez-Polo et al also found that the CIEDE2000 formula mimics the color differences observed by the human eye better than the CIELab formula.<sup>10</sup> In line with these findings, the CIEDE2000 formula was utilized in this study.

In general, the shade matching is quickly accomplished by the dentist using available shade guides from various companies. Most dentists will also ask for the input of their assistant and the patient. This method is very subjective, and the consistency and accuracy can be very unreliable. Many factors can contribute to the inconsistencies of shade matching from age to lighting conditions of the environment.<sup>11</sup> The use of an electronic shade matching instrument for color analysis has been proven to be more reliable when compared to conventional shade matching as it has the capability to convert color into numerical data.<sup>9,12</sup> Kim-Pusateri et al in 2009 evaluated the reliability and accuracy of color measurements from four dental electronic shade-matching devices. They found that the VITA Easyshade was the only color measurement instrument tested that had both reliability and accuracy values greater than 90%.<sup>13</sup> A study by Khurana et al in 2007

concluded that the SpectroShade was greater in consistency when compared to the Easyshade and X-Rite ShadeVision.<sup>14</sup>

Even with spectrophotometers and other shade determining devices, the range of differences in the shade of perceptible and acceptable restorations cannot be agreed upon. In dentistry, the clinical significance of differences in color can be interpreted based on perceptibility and acceptability thresholds. When we talk about the perceptible and acceptable thresholds, we look at the 50:50% perceptibility threshold. This is determined by the lowest difference in color that can be noticed by 50% of observers, and the color difference that is accepted by 50% of observers is determined to be the 50:50% acceptability threshold. Currently, there is little agreement of what is the minimally detectable color difference (perceptibility threshold) and unacceptable color difference (acceptability threshold) in clinical dentistry.<sup>12</sup> These values are subjective and are therefore difficult to establish. Several studies have produced varying values. Johnston et al in 1989 published a study which established the clinical threshold for an acceptable shade match to be 3.7  $\Delta E$  units or less.<sup>15</sup> In 1994, Mahy et al in their experiment found that a  $\Delta E$  of 2.3 was at the limit of what is a perceivable color difference.<sup>17</sup> Douglas et al reported in 2007 that 50% of observers could perceive a color difference of 2.6  $\Delta E$  units, and anything above 5.5  $\Delta E$  units is a clinically unacceptable color match.<sup>16</sup> The threshold for the  $\Delta E_{00}$  formula was determined to be 2.2 by Ghinea et al in 2010.<sup>8</sup> Lastly, Paravina et al in 2015 found the perceptibility and acceptability thresholds to be, 0.8 and 1.8  $\Delta E$  units respectively.<sup>24</sup>

There are many things that need to be taken into account when designing all-ceramic restorations. In 2011, Chaiyabutr et al demonstrated that the color of the abutment tooth and cement, as well as the thickness of the ceramic, all had an effect on the color of the lithium disilicate restorations they tested. They also noted that an opaque cement could not mask a dark abutment

tooth when the ceramic thickness was as thin as 1.0 mm.<sup>18</sup> In areas where space may be limited and all-ceramic crowns are fabricated to a minimal thickness, this can be an esthetic concern when placing a restoration.

Adding to this problem is the fact that implant abutments are frequently cast or milled in metals such as gold and titanium which transmit an unnatural shade through the crown. When restoring an implant a dentist has the choice of either using a ceramic abutment or a metal abutment, typically gold or titanium. In 2009, Sailer et al stated that ceramic abutments currently show promise as a restorative option, but research is limited in direct comparison studies with metal abutments.<sup>19</sup> A more recent study from Zembic et al in 2012, states that at 5 years there is no significant difference between the success of titanium or zirconia abutments.<sup>20</sup> Due to their continued use, finding ways to enhance the esthetic outcome of titanium abutments is a worthwhile endeavor.

One method of altering the titanium abutment color under the ceramic restoration is anodic oxidation, or anodization. Anodization is an electrochemical process that thickens the natural oxide layer of the titanium abutment. The voltage of the direct current running through the solution determines the thickness of the layer, and the thickness of the layer results in the different colors that can be produced on the titanium abutments.<sup>23</sup>

The purpose of this study was to investigate the effect that the underlying color-anodized implant abutment would have on the shade of the lithium disilicate crown. It is hypothesized that the color of the titanium abutment will have a significant effect on the shade of the final all ceramic restoration.

## **MATERIAL AND METHODS**

A 1 mm thick disc was cut from High translucency IPS e.max Press ingots (Ivoclar Vivadent, Schaan, Liechtenstein) of all 16 Vita classical shades using a precision saw (IsoMet Slow Speed Saw, Buehler, Lake Bluff, IL). A one-half inch by 12 inch titanium (Ti-6Al-4V) rod was cut into 5 mm thick disks using the same precision saw. Thirteen titanium disks were each air-abraded (Microblaster, COMCO, Burbank, CA) at 20 psi for 15 seconds with 50  $\mu\text{m}$  aluminum oxide particles, and then anodized (Titanium spectral-colouring Anodizer, Zirkozahn USA, Norcross, Georgia ) at every 10 volts from 0 - 120 volts to generate disks of thirteen different colors.

Each 1 mm thick e.max Press disk was placed upon a full ingot of the corresponding shade with a 40  $\mu\text{m}$  layer of FujiCEM 2 (GC FujiCEM 2, GC America Inc., Alsip, IL) resin-modified glass ionomer cement between them, to act as control. The FujiCEM cement disks were fabricated between 2 glass slabs separated by 5 strips of 8  $\mu\text{m}$  thick articulating paper and allowed to set. The glass slabs were then separated and the cement disks were removed from the glass slab using a razorblade.

A spectrophotometer (Vita Easyshade 4.0, Vita North America, Yorba Linda, CA) was used to measure and store the control shade. The Vita Easyshade was then used to measure the  $\Delta E$  between the shade of each lithium disilicate disk against each color-anodized titanium disk. 3 measurements were taken of each shade on each of the 13 color-anodized titanium disks and then averaged. The spectrophotometer measurements were all collected by the same operator. A 2-way ANOVA was performed with the probability level for statistical significance set at  $\alpha = 0.0001$ , to assess the effect of the color of the anodized titanium on the lithium disilicate disks of all 16 Vita classical shades.

## **RESULTS**

The Vita Easyshade 4 was used to take three shade measurements for each Vita Classical shade of IPS e.max Press against each of the 13 color-anodized titanium disks. The mean  $\Delta E$  for each shade of the 16 Vita classical shades (A1-D4) on all 13 color-anodized titanium disks can be found in Table 1 and seen in Figure 1. The mean  $\Delta E$  values for all shades over all color-anodized titanium disks ranged from 0.7 to 2.97. In general, the results showed a biphasic pattern, with the largest  $\Delta E$  changes at 20-30V, and 90V. The least  $\Delta E$  change was noted at 60V with 50V and 70V close behind.

The mean  $\Delta E$ 's for shade A1 across the various voltages ranged from 1.9 to 2.97, with a mean of 2.47. The lowest  $\Delta E$ , 1.9, was noted at 60V. The mean  $\Delta E$ 's for shade A2 across the various voltages ranged from 1.93 to 2.93, with a mean of 2.46. The lowest  $\Delta E$ , 1.93, was noted at 60V. The mean  $\Delta E$ 's for shade A3 across the various voltages ranged from 1.77 to 2.9, with a mean of 2.28. The lowest  $\Delta E$ , 1.77, was noted at 50V and 70V. The mean  $\Delta E$ 's for shade A3.5 across the various voltages ranged from 1.47 to 2.6, with a mean of 1.95. The lowest  $\Delta E$ , 1.47, was noted at 60V. The mean  $\Delta E$ 's for shade A4 across the various voltages ranged from 1.63 to 2.63, with a mean of 2.14. The lowest  $\Delta E$ , 1.63, was noted at 60V.

The mean  $\Delta E$ 's for shade B1 across the various voltages ranged from 1.7 to 2.97, with a mean of 2.41. The lowest  $\Delta E$ , 1.7, was noted at 60V. The mean  $\Delta E$ 's for shade B2 across the various voltages ranged from 1.6 to 2.93, with a mean of 2.25. The lowest  $\Delta E$ , 1.6, was noted at 60V. The mean  $\Delta E$ 's for shade B3 across the various voltages ranged from 1.5 to 2.7, with a mean of 2.24. The lowest  $\Delta E$ , 1.5, was noted at 60V. The mean  $\Delta E$ 's for shade B4 across the various voltages ranged from 1.4 to 2.63, with a mean of 2.13. The lowest  $\Delta E$ , 1.4, was noted at 60V.

The mean  $\Delta E$ 's for shade C1 across the various voltages ranged from 1.53 to 2.47, with a mean of 1.94. The lowest  $\Delta E$ , 1.53, was noted at 60V. The mean  $\Delta E$ 's for shade C2 across the various voltages ranged from 1.2 to 2.27, with a mean of 1.8. The lowest  $\Delta E$ , 1.2, was noted at 60V. The mean  $\Delta E$ 's for shade C3 across the various voltages ranged from 1.03 to 2.20, with a mean of 1.58. The lowest  $\Delta E$ , 1.03, was noted at 50V and 60V. The mean  $\Delta E$ 's for shade C4 across the various voltages ranged from 0.7 to 1.7, with a mean of 1.24. The lowest  $\Delta E$ , 0.7, was noted at 60V.

The mean  $\Delta E$ 's for shade D2 across the various voltages ranged from 1.4 to 2.5, with a mean of 1.97. The lowest  $\Delta E$ , 1.4, was noted at 60V. The mean  $\Delta E$ 's for shade D3 across the various voltages ranged from 1.5 to 2.8, with a mean of 2.21. The lowest  $\Delta E$ , 1.5, was noted at 70V. The mean  $\Delta E$ 's for shade D4 across the various voltages ranged from 1.5 to 2.87, with a mean of 2.19. The lowest  $\Delta E$ , 1.5, was noted at 60V.

The results for the mean  $\Delta E$  across all shades at the various voltages are noted in Table 2 can be seen in Figure 2. The mean  $\Delta E$  at 0V of anodization was, 1.87. The mean  $\Delta E$  at 10V of anodization was, 2.17. The mean  $\Delta E$  at 20V of anodization was, 2.57. The mean  $\Delta E$  at 30V of anodization was, 2.58. The mean  $\Delta E$  at 40V of anodization was, 2.0. The mean  $\Delta E$  at 50V of anodization was, 1.63. The mean  $\Delta E$  at 60V of anodization was, 1.50. The mean  $\Delta E$  at 70V of anodization was, 1.63. The mean  $\Delta E$  at 80V of anodization was, 2.15. The mean  $\Delta E$  at 90V of anodization was, 2.46. The mean  $\Delta E$  at 100V of anodization was, 2.23. The mean  $\Delta E$  at 110V of anodization was, 2.14. The mean  $\Delta E$  at 120V of anodization was, 2.1.

The 2 way ANOVA of  $\Delta E$  measurements at various voltages revealed a statistically significant effect ( $p < 0.0001$ ) across all shades of the lithium disilicate disks. This indicates that there is a statistically significant difference between each of the shades of ceramic, and the color

of the titanium disks. The null hypothesis should be rejected. Bonferroni post-hoc tests were performed, and shade C4 and C3 were the least affected by the shade of the underlying titanium.

## **DISCUSSION**

This study used spectrophotometric measurements to determine the effect that color-anodized titanium abutments could have on the final all ceramic crowns. A 1mm thick disk was used to simulate the 1 mm minimal axial reduction recommended by the manufacturer. A lithium disilicate material was chosen for its' properties of esthetics and strength. Now, we probably would not typically use a high translucency lithium disilicate when restoring implants, but for the purposes of this study it would show the greatest effect.

As stated earlier, many  $\Delta E$  values for perceptible and acceptable thresholds have been used throughout the years. For the purpose of this study we will compare to the more recent values for the CIE2000 formula found by Paravina et al, 0.8 and 1.8 respectively. The only shade that had a non-perceptible  $\Delta E$  value was C4 at the 60V (0.7) and 70V (0.73) color-anodized titanium disk. 60V in the color-anodizer correlates to a gold color, and 70V is a pink color. In general, the  $\Delta E$  values were significantly lower for the 50V – 70V range for all shades of the lithium disilicate restorations. Consideration may be given to selecting a pink anodized abutment if the patient has a thin gingival biotype. Many other shade and color combinations fell under the acceptability threshold ( $\Delta E$  1.8).

If you were to consider other reported perceptibility and acceptability thresholds from the literature many, if not all, of the shade and color combinations could be clinically acceptable. We should all strive for clinical perfection, but some of our patients may not be as discerning or able to even notice the slight mismatch in shade of the restoration. Depending on location of the

restoration in the mouth, the patient may not even care if there is a slight mismatch. Ultimately, if the patient accepts the restoration shade, it is a success.

## CONCLUSIONS

Within the limitations of this study, the following conclusions can be made:

1. Titanium abutments, color-anodized or not, have an effect on the shade of the final restoration.
2. Shade changes for lithium disilicate crowns shade C4 or C3, are not perceptibly noticeable when placed on gold or pink anodized titanium abutments.
3. For all shades of the lithium disilicate crowns, titanium abutments color-anodized with 50V-70V had the least change in  $\Delta E$ .
4. Consider the use of a pink anodized abutment, if the patient has a thin gingival biotype.

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## TABLES

**Table 1.** Mean  $\Delta E$  values of Vita classical shades at each voltage

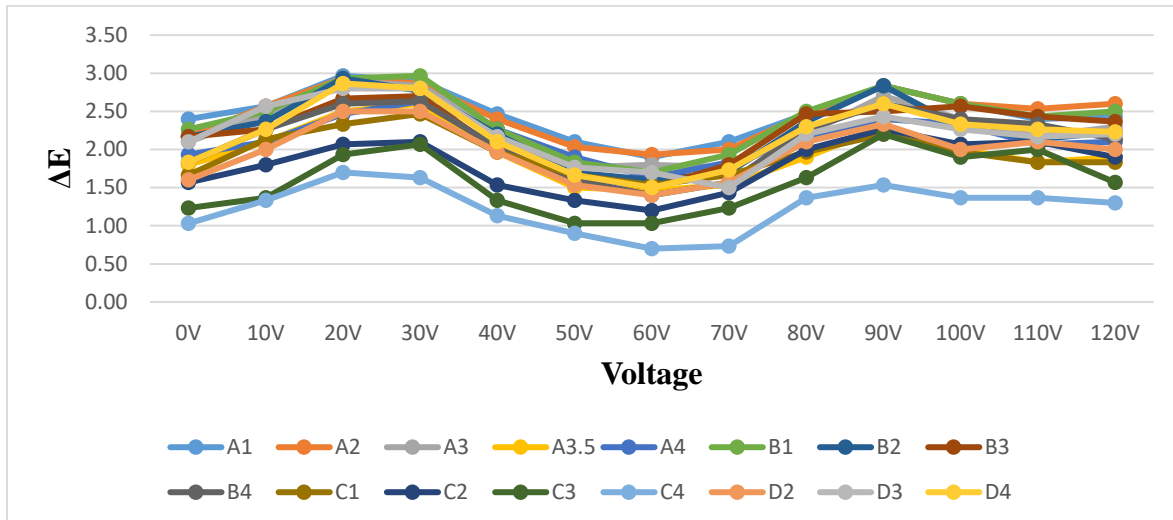
Shade	0V	10V	20V	30V	40V	50V	60V	70V	80V	90V	100V	110V	120V
A1	2.40	2.57	2.97	2.90	2.47	2.10	1.90	2.10	2.47	2.83	2.60	2.40	2.43
A2	2.17	2.57	2.93	2.87	2.40	2.03	1.93	2.00	2.47	2.83	2.60	2.53	2.60
A3	2.10	2.47	2.90	2.83	2.27	1.77	1.80	1.77	2.20	2.70	2.40	2.17	2.30
A3.5	1.80	2.10	2.50	2.60	1.97	1.50	1.47	1.53	1.90	2.30	2.00	1.83	1.90
A4	1.93	2.10	2.47	2.63	2.27	1.90	1.63	1.83	2.13	2.40	2.33	2.07	2.10
B1	2.27	2.50	2.93	2.97	2.27	1.83	1.70	1.93	2.50	2.83	2.60	2.43	2.50
B2	2.17	2.37	2.93	2.77	2.20	1.70	1.60	1.70	2.37	2.83	2.30	2.13	2.23
B3	2.17	2.27	2.67	2.70	2.00	1.67	1.50	1.80	2.47	2.50	2.57	2.43	2.37
B4	1.83	2.27	2.60	2.63	2.03	1.60	1.40	1.57	2.27	2.60	2.40	2.33	2.13
C1	1.67	2.13	2.33	2.47	1.97	1.67	1.53	1.67	1.97	2.20	1.97	1.83	1.83
C2	1.57	1.80	2.07	2.10	1.53	1.33	1.20	1.43	2.00	2.27	2.07	2.10	1.90
C3	1.23	1.37	1.93	2.07	1.33	1.03	1.03	1.23	1.63	2.20	1.90	2.00	1.57
C4	1.03	1.33	1.70	1.63	1.13	0.90	0.70	0.73	1.37	1.53	1.37	1.37	1.30
D2	1.60	2.00	2.50	2.50	1.97	1.53	1.40	1.57	2.10	2.33	2.00	2.10	2.00
D3	2.10	2.57	2.80	2.80	2.17	1.77	1.70	1.50	2.20	2.43	2.27	2.17	2.20
D4	1.83	2.27	2.87	2.80	2.10	1.67	1.50	1.73	2.30	2.60	2.33	2.27	2.23

**Table 2.** Mean  $\Delta E$  values of all Vita classical shades combined at each voltage

	<b>0V</b>	<b>10V</b>	<b>20V</b>	<b>30V</b>	<b>40V</b>	<b>50V</b>	<b>60V</b>	<b>70V</b>	<b>80V</b>	<b>90V</b>	<b>100V</b>	<b>110V</b>	<b>120V</b>
<b>Mean <math>\Delta E</math></b>	1.87	2.17	2.57	2.58	2.00	1.63	1.50	1.63	2.15	2.46	2.23	2.14	2.10

## FIGURES

**Figure 1.** Mean  $\Delta E$  values of Vita classical shades at each voltage



**Figure 2.** Mean  $\Delta E$  values of all Vita classical shades combined at each voltage

