Effect of Manufacturer and Laboratory Processing Variability on Pre-shaded Ceramic Color

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Acknowledgements:

Declaration of Interest: None

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or non-for-profit sector.

Distribution Statement

Distribution A: Public Release.

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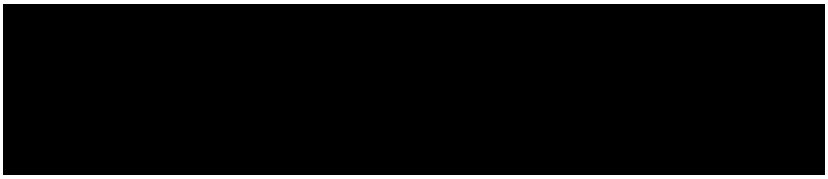

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Date: **06/12/2019**

ABSTRACT

Statement of Problem. While there has been an abundance of research on color and shade reproduction of ceramic restorations, the esthetic predictability of pre-shaded ceramic materials is still uncertain as there is currently a lack of information on the variability in their color as manufactured and after laboratory processing.

Purpose. The objective of this study was to determine by spectrophotometric analysis the difference (ΔE) between the labeled and inherent shade of three different pre-shaded ceramics and assess first, the *manufacturer* variability and second, the *laboratory processing* variability.

Material and Methods. First, to assess manufacturer variability, 10 different lots from each pre-shaded A2 ceramic system, IPS E.max CAD LT (EXC), IPS E.max Press LT (EXP), and Cercon HT (CRC), were used to fabricate 90 shade tabs (three from each lot) of 1.5 mm in thickness according to manufacturer's instructions. Tabs from the same lot were processed at the same time and all samples processed on the same day to isolate manufacturer variability from laboratory processing variability. The ΔE, along with ΔL, ΔC, and Δh values for each specimen were measured using a spectrophotometer to assess the difference between the manufacturer intended A2 shade and the actual shade. To assess laboratory processing variability, 30 tabs each from the same three ceramic systems were fabricated: three tabs per day on three different days, selected from the lot with the closest ΔE to the mean from the previous manufacturer variability study. The average ΔE of the three tabs from each day was calculated utilizing the same process as in the previous study to assess the difference between the manufacturer intended A2 shade and the actual shade after each day of laboratory processing. The differences in the color values was determined by means of one-way analysis of variance ($\alpha = 0.05$).

Results. All the ΔE values measured for both the manufacturer and laboratory processing variability studies were within the clinically acceptable tolerance of 5.5 ΔE units. On the other hand, only the CRC samples can be considered to have a perfect shade match to A2 (ΔE < 3.7) with no perceptible shade discrepancies (ΔE < 2.6) for all its samples. The overall mean ΔE for the EXP, EXC, and CRC groups were: 4.26, 3.62, and 1.62, respectively. The differences in shade coordinates indicate that chroma is the chief factor contributing to the larger ΔE seen in the EXP and EXC samples. One-way ANOVA of ΔE measurements revealed statistically significant difference between each lot from all three materials tested. Shade discrepancies, when assessing for variability as a result of laboratory processing procedures, were also found to be statistically significant except for the EXC group.

Conclusions. Variabilities between the labeled and inherent shade of IPS e.max lithium disilicate and Cercon zirconia do exist, are manufacturer-based, and vary depending on the material. The discrepancy, however, is still within the threshold for being clinically acceptable (ΔE < 5.5). While laboratory processing variabilities may be present, they are clinically negligible. Of the ceramic systems tested, Cercon zirconia is the truest to its labeled shade. The labeled shade for IPS e.max material may be in the acceptable range for the desired shade but the difference in color is perceptible.

CLINICAL IMPLICATIONS

Color differences were detected between pre-shaded ceramic materials and their manufacture labeled shade after processing. The differences were small enough to be considered visually undetectable and clinically unimportant for Cercon zirconia. However, differences in lithium disilicate were found to be within the threshold for an acceptable match, but clinically detectable and at or beyond the threshold for a perfect shade match. These inherent discrepancies in the

shade should be taken into consideration, especially when using lithium disilicate in esthetic cases.

INTRODUCTION

Achieving natural looking restorations is one of the most challenging aspects of dentistry. While certain characteristics of the natural dentition, such as the size, shape, and surface properties can be mimicked easily, the ability to successfully match the shade of a restoration to the adjacent natural dentition has proven to be a difficult endeavor.[1,7] In the last few decades, ceramics have evolved significantly and have been widely used for esthetic restorations due to their biocompatibility and improved esthetic when compared to traditional porcelain-fused-to-metal (PFM) restorations.[1] A number of ceramic materials and systems are currently available for clinical use, ranging from the highly esthetic feldspathic ceramics to the tougher and stronger polycrystalline ceramics like zirconia.[8] Pre-shaded ceramic systems have alleviated some of the burden in the shade replication process with the addition of metal oxides or polyvalent coloring ions that allows for a more homogenously colored material versus the need for coloration through manual staining.[9] However, despite the added ease associated with the use of pre-shaded ceramic materials, shade replication with ceramic systems is still problematic for a variety of reasons.

A successful color match of a restoration requires both proper shade selection and replication.[1,16] Shade selection can be accomplished by two means, visual assessment or instrumental color analysis.[1,7] Conventional shade matching is typically accomplished using a shade guide as a visual assessment tool. However, the subjectivity of this method makes it unreliable, as it is neither consistent nor accurate and often leads to improper shade selection.[16-20,25] Inconsistencies from visual assessment can result from multiple factors such as lighting

conditions, environment, or even physiologic effects such as aging.[1,10,23,24] Instrumental color analysis, such as the VITA Easyshade spectrophotometer, proves to be a more dependable alternative to conventional shade selection as it has the ability to translate color into quantifiable data.[12,13,16-20,25] Their use, when compared with visual observation, increases accuracy of the shade selection by 33% and provides a more objective match in 93.3% of cases.[16,25]

Most technology-based shade systems measure the spectral reflectance of an object and express it in the three coordinate values of the L*a*b* color space established by the Commission Internationale de l'Eclairage (CIE).[2,3,15] The color difference (ΔE^*_{ab}) between two objects can then be quantified by calculating the differences between respective coordinate values of each object using the following equation: $\Delta E^*_{ab} = [(\Delta L^{*2}) + (\Delta a^{*2}) + (\Delta b^{*2})]^{1/2}$. Color differences can also be expressed using the CIE L*C*h coordinates, which are similar to the L*a*b* color space, except for the fact that color differences are expressed in cylindrical rather than rectangular coordinates. In this color space, L* indicates lightness, C* represents chroma, and h is the hue angle.

Currently, there is little agreement on the magnitude of minimally detectable color difference (perceptibility threshold) and unacceptable color difference (acceptability threshold) in clinical dentistry.[4-6] These values are subjective and are therefore difficult to establish; consequently, various studies have produced a wide range of values. In 1989, Johnston and Kao[4] published a study in which the clinical threshold for an acceptable or perfect shade match was determined to be a ΔE of 3.7 units or less. In an in vivo study, Douglas et al[5] reported that 50% of observers could perceive a color difference of 2.6 ΔE units and established the threshold for a clinically unacceptable color match intraorally at 5.5 ΔE units.

In regard to shade replication, variability can arise in almost every aspect of the fabrication process and errors associated with the shade replication of dental ceramics have been documented. Douglas et al[11] studied the porcelain color reproduction by commercial laboratories and found that the ability to reproduce the color of a target shade tab differed among laboratories. The variability in color reproduction by a given ceramist accounted for nearly 100% of the allowable 3.7 ΔE units of color difference for a perfect shade match according to a study by Johnston and Kao[4].[11] Al-Wahadni et al[14] examined the effects of the veneering technique (layering, pressing, and digital veneering) on the shade reproducibility of zirconia-based crowns and found that the technique had a significant influence on the shade reproducibility.

In addition to the issues attributed to fabrication and shade selection discussed above, there is currently no literature that examines the variabilities in the inherent color of the materials themselves (as produced by the manufacturer), specifically with regard to pre-shaded ceramic materials. Consequently, it is important to understand where variabilities could arise that may affect the final color of these restorations, and the magnitude and direction of these variances. The aim of this study was to determine by spectrophotometric analysis the difference (ΔE) between the manufacturer labeled and actual final shade of three different pre-shaded ceramics to assess the *manufacturer* and *laboratory fabrication process* variability. The following three hypotheses were made: 1) The inherent color of the materials, both as manufactured and after laboratory processing, will vary from their manufacturer labeled shade, but the dissimilarity will be within the tolerance for a clinically acceptable shade match; 2) Shade discrepancies will be statistically insignificant between different lots of the same material due to manufacturer variability; and 3) Shade variability from laboratory processing procedures will be statistically insignificant.

MATERIAL AND METHODS

Three monolithic A2 pre-shaded ceramic systems were evaluated: IPS e.max CAD LT, IPS e.max Press LT, and Cercon HT (Table 1). To assess manufacturer variability, ten different lots of each ceramic system were used to fabricate 90 tabs (three tabs per sample, 30 per ceramic system) of 1.5 mm in thickness. IPS E.max CAD (EXC) were cut into disks of 1.5 mm using a water lubricated precision saw (IsoMet Slow Speed Saw, Buehler, Lake Bluff, IL) and then crystallized according to manufacturer's instructions. Freeform tabs measuring 12 mm x 12 mm x 1.5 mm were designed using a digital software (3Shape CAD Software, 3Shape A/S, Copenhagen, Denmark), milled as wax patterns (ProArt Wax Disc, Wieland Dental + Technik GmbH, Pforzheim, Germany), and then pressed in IPS E.max Press LT (EXP) according to manufacturer's instructions. Cercon HT (CRC) tabs of the same size were designed in the same manner, milled, and then sintered according to manufacturer's instructions. Tabs of the same lot were processed at the same time and all samples were processed on the same day to minimize processing variability. All tabs were measured to ensure uniformity in thickness.

A dental spectrophotometer (Vita Easyshade Advance 4.0, Vita Zahnfabrik, Bad Säckingen, Germany) was used to measure and calculate the ΔE of each tab compared to the A2 shade standard stored in the software of the spectrophotometer. Shade measurements were performed by positioning the probe tip of the spectrophotometer against the center of the flat ceramic tab, with the other two tabs in the same sample serving as a foundation to prevent the background color to have an effect on the shade measurement. Illumination of the specimens was achieved by directing the LED light from the periphery of the tip onto the specimen surface. Throughout the study, the shade was measured by the same operator with the same spectrophotometer. This spectrophotometer has the ability to determine the object's color within

the color space and display the values for each coordinate (L*, C*, and h) as well as automatically calculate the ΔE based on these measurements. The ΔE was measured three times for each specimen from each lot. The average of the three recorded values was calculated to assess the difference between the intended and actual shade of each ceramic material.

Laboratory processing variability was assessed through the fabrication of nine tabs per ceramic system: three tabs per day on three different days from the lot with the closest ΔE to the mean from the previous study. The average ΔE of the three tabs from each day was determined using the same technique described above to assess manufacturer variability. Clinical significance was determined by comparing color difference values to the perceptibility and acceptability thresholds as determined by Douglas et al[5,] and Johnston and Kao[4], where $\Delta E > 2.6$ was considered clinically perceptible, $\Delta E < 3.7$ was considered a perfect match, and $\Delta E > 5.5$ was considered clinically unacceptable. The differences in the color values were determined by means of a one-way analysis of variance (ANOVA) with the probability level for statistical significance set at $\alpha = 0.05$.

RESULTS

Using the Vita Easyshade spectrophotometer, three shade measurements were taken for each A2 shade tab in each sample group. For the study looking at manufacturing variability, the mean ΔE for each lot, along with the mean CIE coordinates (ΔL, ΔC, Δh) between each ceramic specimen and the programed shade are listed in Tables 2, 3, and 4. The overall mean ΔE for the EXP, EXC, and CRC groups were: 4.26 units, 3.62 units, and 1.62 units, respectively. The mean ΔE for the EXP group ranged from 3.52 ± 0.12 to 5.08 ± 0.27, with the mean shade coordinate differences of $\Delta L = -0.75 \pm 0.22$, $\Delta C = -4.11 \pm 0.29$, $\Delta h = 1.25 \pm 0.3$. Although the collective shade differences (ΔE) of each lot are considered clinically acceptable, the differences are

clinically perceptible. The differences in shade coordinates indicate that the chroma is the chief factor contributing to the shade difference. The one-way ANOVA ($\alpha = 0.05$) of ΔE measurements revealed a statistically significant main effect [F (9, 80) = 57.27, $p < 0.001$] (Table 5). This indicates that there is a statistically significant difference between each of the 10 lots and, therefore, the null hypothesis should be rejected.

For the EXC group, the mean ΔE ranged from 3.39 ± 0.17 to 3.86 ± 0.24 with mean shade coordinate differences of $\Delta L = -0.58 \pm 0.15$, $\Delta C = -3.57 \pm 0.16$, $\Delta h = 0.02 \pm 0.2$. The differences are considered clinically perceptible but still acceptable, with the chroma being the chief varying factor here as well. The one-way ANOVA of ΔE measurements revealed a statistically significant main effect [F (9, 80) = 10.33, $p < 0.001$] indicating that there is a statistically significant difference between each of the 10 lots and, therefore, the null hypothesis should be rejected (Table 6).

For the CRC group, the mean ΔE ranged from 1.51 ± 0.06 to 1.71 ± 0.09 with mean shade coordinate differences of $\Delta L = -0.48 \pm 0.17$, $\Delta C = -0.17 \pm 0.36$, $\Delta h = -4.71 \pm 0.29$. Unlike the EXP and EXC materials, the shade differences are clinically not perceptible according to the thresholds set by Douglas et al[5]. The one-way ANOVA of ΔE measurements revealed a statistically significant main effect [F (9, 80) = 2.07, $p < 0.042$] (Table 7). This indicates that there is only a marginally-statistically significant difference between each of the ten lots and, therefore, the null hypothesis should be rejected.

In assessing for discrepancies as a result of processing variability, it was found that nearly all specimens, regardless of material, had a shade difference that was clinical perceptible but was still within the acceptability tolerance (Table 8-10). The mean ΔEs were consistent with the measurements recorded from the previous study with the exception of the CRC group, where

the mean ΔE increased from a range of about 1.51 - 1.71 to 2.39 - 2.79 units. To verify the findings, a second test was run using another sample and the results were similar. The one-way ANOVA showed that there was a statistically significant difference within the EXP and CRC samples ([F (2, 24) = 36.09, p < 0.001], [F (2, 24) = 7.98, p < 0.002], respectively) (Table 11 and 13). However, variability from processing was not statistically significant in the EXC group [F (2, 24) = 2.20, p < 0.133] (Table 12).

DISCUSSION

Through spectrophotometric analysis, this study evaluated the presence of manufacturer and processing variability in shade discrepancies between the labeled and inherent shades of three different pre-shaded ceramics. Based on the results of this study, it was found that shade discrepancies were present but are still within the tolerance for an acceptable shade match (ΔE < 5.5). The extent of the discrepancies, however, varied based on the material. The results of this study support the rejection of the null hypothesis that shade discrepancies will be statistically insignificant between lots of the same material due to manufacturer variability. The other hypothesis, that shade discrepancies from processing procedures will also be statistically insignificant, was partially rejected.

Although all the ΔE values measured in both studies were within the clinically acceptable tolerance of 5.5 ΔE units, only the CRC samples would be considered to have a perfect shade match to A2 (ΔE < 3.7) with no perceptible shade discrepancies (ΔE < 2.6) for all its samples (Table 4 and 10). When the ΔE values of the three ceramics were compared, the CRC group had the lowest ΔE values and the EXP group had the greatest ΔE values (Table 2, 3, 4). The mean ΔE value for the EXC group was within the threshold of being considered a perfect match; however, the shade discrepancy was considered clinically perceptible (ΔE > 2.6). This suggests

that CRC materials are the truest to its labeled shade, while perceptible variabilities are apparent in the EXP and EXC groups. What can be concluded from the data is that there is an existing discrepancy in the inherent color of pre-shaded ceramic materials compared to the labeled shade that is manufacturer-based. Although the variability in ΔE units between each lot of material may be statistically significant, it may not be clinically relevant due to the small magnitude of the variance and the fact that all the ΔE values were within the clinically acceptable tolerance of 5.5 ΔE units (Table 2-7).

Where the shade difference was most profound was in the C* coordinates. This indicates that for both EXP and EXC, the samples were duller in chroma compared to the programmed A2 shade. In both samples, the ΔC values were in the range of between -3.3 to -5.0 units, collectively, resulting in a ΔE of between 3 to 5 units (Table 2 and 3). In the CRC samples, the greatest discrepancy was in the Δh values, which were between -4.39 to -5.10 units (Table 4). This, however, only resulted in a ΔE of 1.51 to 1.71 units. These results would allow one to believe that ΔC values have a greater effect on ΔE than Δh values.

Shade discrepancies as a result of processing procedures was statistically significant within the EXP and CRC samples ([$F(2, 24) = 36.09$, $p < 0.001$], [$F(2, 24) = 7.98$, $p < 0.002$], respectively); however, variability from processing was not statistically significant in the EXC group ([$F(2, 24) = 2.20$, $p < 0.133$]) (Table 11, 12, and 13). Therefore, the null hypothesis, that shade disparities will be insignificant due to processing procedures, can only be partially rejected. One possibility for such findings could be the fact that EXP and CRC materials require more tedious processing procedures, likely resulting in higher variability in ΔE values compared to the EXC samples. However, despite finding statistically significant variability within the EXP

and CRC groups, the results are not clinically significant because the ΔE values are still within the thresholds seen in the previous study.

The fact that the majority of ΔE values for the EXP group have already surpassed both the threshold for clinical imperceptibility (ΔE > 2.6) and a perfect shade match (ΔE > 3.7), indicates that there is already a semblance of a mismatch, despite the ΔE values still being within the acceptability threshold (ΔE < 5.5). Ultimately, it would be up to the provider and the patient to determine if the shade is an acceptable match. However, one has to consider that any additional modifications to the EXP specimens could potentially push the ΔE over the acceptability threshold of 5.5 ΔE units and any additional modifications to the EXC specimens could potentially push the ΔE over the threshold of 3.7 ΔE units for a perfect match.

Considering the fact that the effects of polishing and glazing procedures were not assessed in this study, a conclusion cannot be drawn regarding how these procedures might affect the ΔE. In a study by Kim et al[21], it was found that a perceptible color difference can be detectable after polishing of monolithic zirconia. Further, it was concluded that polishing decreases the lightness, and glazing also decreases the lightness, but increases the yellowness of monolithic zirconia. In an in vitro study, Alp et al[22] found that polishing of lithium disilicate ceramic induces color changes that were perceivable, and that glazing had less of an effect on color stability. Quantification of the change in ΔE as a result of final surface treatments may be something to examine in a future study. It could be recommended that when using lithium disilicate ceramic materials in esthetic cases, a shade lighter than the one desired should be selected since the inherent color of the material is already at or beyond the threshold of a perfect match prior to polishing and glazing.

CONCLUSIONS

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

1. Variabilities between the manufacturer labeled and inherent shade of IPS e.max lithium disilicate and Cercon zirconia existed, however, they were within the threshold of clinical acceptability. The shade discrepancies were manufacturer-based and varied depending on the material.

2. While processing variabilities may be present, they were clinically negligible.

3. Of the ceramic systems tested, Cercon zirconia was the truest to its labeled shade.

4. The manufacturer labeled shade for IPS e.max lithium disilicate material may be in the acceptable range for the desired shade but the difference in color was perceptible.

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TABLES

Table 1. Materials Investigated

Material	Manufacturer
IPS E.max Press LT (EXP)	Ivoclar Vivadent, Schaan, Liechtenstein
IPS E.max CAD LT (EXC)	Ivoclar Vivadent, Schaan, Liechtenstein
Cercon HT (CRC)	DeguDent GmbH, Hanau-Wolfgang, Germany

LT, low translucency; HT, high translucency

Table 2. EXP group: means of ΔE, ΔL*, ΔC*, and Δh within each lot

Lot	Mean ΔE	Mean ΔL	Mean ΔC	Mean Δh
1	3.66±0.24	-0.37±0.26	-3.61±0.23	0.69±0.34
2	4.29±0.22	-0.53±0.29	-4.21±0.23	1.71±0.40
3	4.48±0.22	-0.96±0.21	-3.99±1.03	1.76±0.28
4	3.77±0.18	-0.89±0.08	-3.64±0.19	0.49±0.22
5	3.52±0.12	-1.56±0.22	-3.17±0.18	-0.14±0.27
6	4.57±0.18	-0.63±0.24	-4.48±0.19	1.80±0.28
7	4.26±0.21	-0.66±0.18	-4.18±0.22	1.47±0.33
8	4.96±0.12	-0.89±0.18	-4.84±0.13	1.54±0.15
9	5.08±0.27	-0.40±0.34	-5.00±0.26	2.37±0.38
10	4.04±0.26	-0.67±0.19	-3.98±0.25	0.86±0.34
Mean	4.26±0.20	-0.75±0.22	-4.11±0.29	1.25±0.30

EXP, IPS E.max Press LT. Values are given as mean ± SD.

Table 3. EXC group: means of ΔE, ΔL*, ΔC*, and Δh within each lot

Lot	Mean ΔE	Mean ΔL	Mean ΔC	Mean Δh
1	3.46±0.16	-0.78±0.14	-3.40±0.17	-0.31±0.14
2	3.39±0.17	-0.67±0.12	-3.30±0.21	-0.29±0.21
3	3.67±0.14	-0.36±0.09	-3.64±0.13	0.14±0.16
4	3.56±0.19	-0.73±0.23	-3.47±0.18	0.18±0.16
5	3.81±0.09	-0.41±0.12	-3.76±0.10	0.07±0.30
6	3.86±0.24	-0.51±0.24	-3.82±0.23	0±0.24
7	3.63±0.18	-0.54±0.14	-3.60±0.16	0.03±0.19
8	3.86±0.19	-0.54±0.10	-3.80±0.21	0.34±0.29
9	3.57±0.07	-0.61±0.22	-3.50±0.10	0.08±0.18
10	3.43±0.13	-0.67±0.11	-3.38±0.14	-0.04±0.15
Mean	3.62±0.16	-0.58±0.15	-3.57±0.16	0.02±0.20

EXC, IPS E.max CAD LT. Values are given as mean ± SD.

Table 4. CRC group: means of ΔE, ΔL*, ΔC*, and Δh within each lot

Lot	Mean ΔE	Mean ΔL	Mean ΔC	Mean Δh
1	1.64±0.17	-0.56±0.19	-0.19±0.44	-4.78±0.31
2	1.51±0.06	-0.16±0.19	-0.60±0.36	-4.29±0.35
3	1.59±0.09	-0.40±0.17	-0.57±0.24	-4.48±0.33
4	1.60±0.12	-0.57±0.13	0.17±0.40	-4.58±0.20
5	1.60±0.12	-0.60±0.10	0.19±0.25	-4.63±0.21
6	1.59±0.11	-0.47±0.20	-0.34±0.36	-4.59±0.32
7	1.71±0.09	-0.51±0.15	-0.03±0.34	-5.10±0.29
8	1.67±0.10	-0.50±0.16	-0.08±0.34	-4.96±0.28
9	1.67±0.16	-0.46±0.18	-0.09±0.40	-4.93±0.36
10	1.64±0.11	-0.54±0.19	-0.12±0.41	-4.81±0.30
Mean	1.62±0.11	-0.48±0.17	-0.17±0.36	-4.71±0.29

CRC, Cercon HT. Values are given as mean ± SD.

Table 5. One-way analysis of variance of ΔE within the EXP group

Source of Variation	Sum of Squares	d*f*	Mean Square	F	*P*-value
Between Groups	22.45	9	2.49	57.27	< 0.001
Within Groups	3.48	80	0.04		
Total	25.93	89			

EXP, IPS E.max Press LT.

Table 6. One-way analysis of variance of ΔE within the EXC group

Source of Variation	Sum of Squares	d*f*	Mean Square	F	*P*-value
Between Groups	2.45	9	0.27	10.33	< 0.001
Within Groups	2.11	80	0.03		
Total	4.56	89			

EXC, IPS E.max CAD LT.

Table 7. One-way analysis of variance of ΔE within the CRC group

Source of Variation	Sum of Squares	d*f*	Mean Square	F	*P*-value
Between Groups	0.26	9	0.03	2.07	0.042
Within Groups	1.10	80	0.01		
Total	1.36	89			

CRC, Cercon HT.

Table 8. EXP group: means of ΔE, ΔL*, ΔC*, and Δh on three different processing days

Date of Processing	Mean ΔE	Mean ΔL	Mean ΔC	Mean Δh
9-Oct	4.08±0.40	-0.33±0.12	-4.03±0.40	1.92±0.44
26-Oct	4.26±0.12	-0.27±0.12	-4.19±0.13	2.19±0.45
6-Nov	5.11±0.23	-2.69±0.77	-4.47±0.37	1.53±0.47

EXP, IPS E.max Press LT. Values are given as mean ± SD.

Table 9. EXC group: means of ΔE, ΔL*, ΔC*, and Δh on three different processing days

Date of Processing	Mean ΔE	Mean ΔL	Mean ΔC	Mean Δh
20-Nov	3.58±0.10	-0.61±0.13	-3.50±0.10	-0.02±0.12
29-Nov	3.60±0.09	-0.56±0.11	-3.57±0.07	0.17±0.09
7-Dec	3.68±0.13	-0.79±0.09	-3.59±0.14	0.06±0.16

EXC, IPS E.max CAD LT. Values are given as mean ± SD.

Table 10. CRC group: means of ΔE, ΔL*, ΔC*, and Δh on three different processing days

Date of Processing	Mean ΔE	Mean ΔL	Mean ΔC	Mean Δh
09-Oct	2.61±0.23	1.20±0.44	-2.08±0.20	-3.18±0.15
28-Oct	2.79±0.24	1.43±0.13	-2.19±0.33	-3.20±0.12
19-Nov	2.39±0.16	0.80±0.13	-1.87±0.19	-4.24±0.15

CRC, Cercon HT. Values are given as mean ± SD.

Table 11. One-way analysis of variance of ΔE in EXP group over three different processing days

Source of Variation	Sum of Squares	d*f*	Mean Square	F	*P*-value
Between Groups	5.49	2	2.75	36.09	< .001
Within Groups	1.83	24	0.08		
Total	7.32	26			

EXP, IPS E.max Press LT.

Table 12. One-way analysis of variance of ΔE in EXC group over three different processing days

Source of Variation	Sum of Squares	d*f*	Mean Square	F	*P*-value
Between Groups	0.05	2	0.02	2.20	0.133
Within Groups	0.27	24	0.01		
Total	0.32	26			

EXC, IPS E.max CAD LT.

Table 13. One-way analysis of variance of ΔE in CRC group over three different processing days

Source of Variation	Sum of Squares	d*f*	Mean Square	F	*P*-value
Between Groups	0.72	2	0.36	7.98	0.002
Within Groups	1.09	24	0.05		
Total	1.81	26			

CRC, Cercon HT.