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## Research Article

# Effect of Two Vital Bleaching Agents on the Color Properties of the Low-Fusing Dental Ceramics

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# Effect of Two Vital Bleaching Agents on the Color Properties of the Low-Fusing Dental Ceramics

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## Abstract

**Statement of the problem:** The effects of vital bleaching agents on color properties of dental tissues and direct restorative materials are well documented. However, there is a lack of information about the effects of these agents on low- fusing dental ceramics.

**Objective:** The aim of the present study is the in vitro evaluation of the effects of two vital bleaching agents on the color features of three different dental ceramic materials.

**Materials & Methods:** 60 sample discs of two different feldspathic ceramics and a full ceramic system were fabricated 12mm in diameter according to the manufacturers' instructions. The 1st feldspathic group was designated as C (n=20), the 2nd V (n=20), and the full ceramic group F (n=20). Prior to bleaching, L*a*b* values of each glazed sample were measured using a colorimeter. Each sample group was divided in two for the bleaching in two different derivations. Whereas the subgroups exposed to 10% carbamide peroxide were designated CR, VR, and FR; subgroups exposed to 16% carbamide peroxide were entitled CN, VN, and FN. Following bleaching, color measurements were repeated. Descriptive analysis of all data, consisting L*a*b*, ΔL*, Δa*, Δb*, and ΔE values of the two measurements, were performed. Obtained results were statistically analyzed with Kruskal-Wallis test.

**Results:** Comparisons revealed no significant difference between the ΔL*, Δa*, Δb* values of the 6 groups. Also no significance was found between the ΔE results of the FR, FN and VN, VR groups (P = 0.1, P = 0.3). However, there was a significant difference between the ΔE values of the groups CN and CR (P = 0.001).

**Conclusion:** Vital bleaching agents have the potential to alter the color features of ceramic materials.


**Keywords:** Bleaching, Vital Bleaching, Low-Fusing Ceramics, Feldspathic Ceramics, Full Ceramic System, Color Changes, Colorimetric Measurement.

## Introduction

Nowadays, dental esthetics has become a factor that affects one's confidence, self-esteem, quality of life, and even determines the social perception about the personality of the individual.[1-3] The most important determinants of dental esthetics are the proportions and morphology of the teeth in the esthetic zone coherent with periodontal tissues, harmony of the pink and white contours, and color.[4-7]

Tooth color is a notably complex visual feature originated by the coalescence of the three color attributes (hue, chroma, and value) and characterized with translucency and surface properties.[8,9] Tooth color is vulnerable to the intrinsic factors such as aging, as well as extrinsic stains called chromogens that accumulated on the surface.[6,10,11] Extrinsic stains are in effect on the color characteristics with the eruption of the teeth.[10]

Some nutriments, beverages such as wine, tea, and coffee and smoking are the major extrinsic stains.[10,12,13] Moreover, chromogens accumulate not only on tooth but also on the surfaces of direct and indirect restorations.[13,14] 19 to 65 % of the population in developed countries has reported not to be content with their dental appearance and tooth color characteristics.[6,9]

The substantial impact of media both printed and electronic seemed to expand the dental aesthetic awareness especially about the discolored teeth.[10] Especially in the last 20 years, the desire of having whiter teeth have gradually increased and vital bleaching procedures becomes more popular with each day[15]. Today, whereas vital bleaching can be performed by dental practitioners entirely in dental offices or initiated in-office and continued at home by the patients, there are over-the-counter bleaching boxes on the market to be used without professional supervision.[15-17]

Vital bleaching can be identified as the procedure of the degradation of the chromogens using certain chemicals in order to lighten the tooth color.[10] These chemical components are Hydrogen peroxide (HP) and Carbamide peroxide (CP).[17] The chemicals and their derivations may differ significantly from one commercial product to another.[10,15-17]

Although both agents can alter the color features of tooth, it is reported that they also have the potential to affect the microhardness and surface characteristics of enamel.[17] However, majority of the adult population may have one or more indirect restorations[18] and the knowledge on the effects of vital bleaching agents on dental porcelain color features is limited.

The aim of this study is the in-vitro evaluation of the effects of two vital bleaching agents on the color properties of three different dental ceramic materials. As the null hypothesis, no

changes in color features of glazed ceramic surfaces are expected following the exposure to bleaching agents.

**Materials & Methods**

The research carried out in six steps.

-Fabrication of the metal mold to be used for the standardization of the sample production

-Production of the ceramic samples

-Pre-bleaching color measurements

-Bleaching procedure using two different agents

-Post-bleaching color measurements

-Statistical analysis

**-Fabrication of the metal mold to be used for the standardization of the sample production**

A stainless steel mold was fabricated using a computer numerical control machine with cut-back technique in order to standardize the dimensions and the surface of the samples. The mold was composed of a cylinder (12mm in length), a plunger/piston (12mm in diameter) that fits precisely in to the cylinder, and a screw-stud system to locate and immobilize the plunger/piston in the set position. To achieve the fabrication of the samples in standard thickness, three marks were milled at 0.3, 0.4, 1.2 mm elevations in the cylinder. Fabricated mold (Figure 1) was then cleaned in ultrasonic cleaner with ethyl alcohol (%10) and distilled water respectively.

**Figure 1.** Stainless steel mold for the standardized veneering purposes.

**-Production of the ceramic samples**

For the samples, two feldspathic porcelain for metal-ceramic restorations and a leucite-reinforced all ceramic material were selected.

The feldspathic porcelain materials used in the study were Ceramco 3 (Dentsply Sirona, Germany) and VMK 95 (Vita Zahnfabrik H. Rauter GmbH, Germany). Initially, 40 metal discs were fabricated 0.3mm in thickness and 12mm in diameter with lost-wax technique using wax patterns produced in a metal mold for standardisation purposes. A base metal alloy (Remanium® LFC, Dentaurum, Germany) was used for casting the discs. Following the smoothing, polishing, oxidation, and sandblasting respectively the discs were coated with opaque porcelain layers 0.1mm in thickness and fired. Then the discs were placed in the metal mold for the porcelaine veneering procedure. Using condensation technique, 1.4 ± 0.1mm body-dentin and 0.4 ± 0.1 mm enamel porcelain layers were applied to each disc. After firing phase, samples were grinded with 180, 220, 320 grit sandpapers, and glazed (Figure 2). Sample group fabricated with Ceramco 3 (n = 20) was designated “C” whereas VMK95 group (n = 20) designated “V”.

Leucite-reinforced all-ceramic discs (n = 20) were produced using FinneseTM All Ceramic (Dentsply, USA) ingots in the same dimensions (12mm diameter, 2.2 ± 1mm thickness) according to the manufacturer’s recommendations. Finally, fabricated discs were glazed. Samples (n = 20) produced with Finesse were recorded as group ‘F’ (Figure 2).

**Figure 2.** 60 sample discs ready for bleaching stage.

Each group was divided in two subgroups before the bleaching stage. The subgroup which would be exposed to %16 Carbamide peroxide (Nite-White, Discus Dental, Inc, USA) was entitled "N" and the other subgroup on which %10 carbamide peroxide gel (Rembrant, Dent-Mat Corp, USA) would be applied designated "R". Thus, 60 sample discs were divided in 6 study groups; CN, VN, CR, VR, VR, and FR. Its group initial and sample number were milled on the back of each disc.

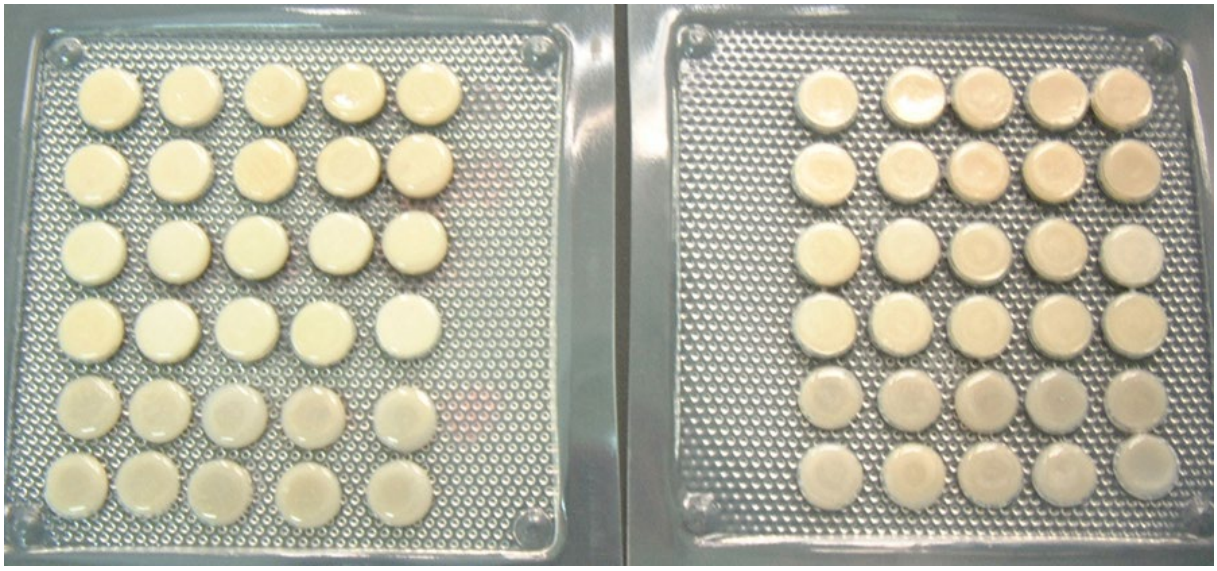
**-Pre-bleaching color measurements**

Prior to the bleaching, color values of all samples were measured with a colorimeter (Minolta 321, Minolta GmbH, Japan) and the results were recorded as L*a*b* data (1$^{st}$ Measurement). Colorimeter readings were performed on the glazed surfaces after the device calibrated as instructed by the manufacturer.

**- Bleaching procedure using two different agents**

Samples were placed in custom-made clear resin trays (Figure 3), and bleaching gel was applied on the exposed glazed surfaces of the discs. After 8 hours of exposure the samples were cleaned with a toothbrush under running water and preserved at room temperature in distilled water until the next bleaching session. All samples were undergone bleaching for 14 days.

**Figure 3.** Samples in trays.



**-Post-bleaching color measurements**

Color measurements were repeated following the bleaching stage (2nd Measurement). To assess the effect of bleaching on color features obtained L*a*b* values were processed through a formula used in CIEL*a*b* color system[9]:

$$\Delta E\ (L^*a^*b^*) = [(L^*_1-L^*_2)^2 + (a^*_1-a^*_2)^2 + (b^*_1-b^*_2)^2]1/2$$

The effect of bleaching on the L* component of color is evaluated with the formula[9]:

$$\Delta\ L^* = L^*_1 - L^*_s.$$

The negative Δ L* values were accepted as the sample color became lighter and positive results indicated that a darker color acquired.

The effect of bleaching on the a* component of color is evaluated with the formula[9]:

$$\Delta\ a^* = a^*_1 - a^*_s$$

The negative Δ a* values were accepted as the sample color became greener and positive results indicated that a redder color acquired.

The effect of bleaching on the b* component of color is evaluated with the formula[9]:

$$\Delta\ b^* = b^*_1 - b^*_s$$

The negative Δ b* values were accepted as the sample color became bluer and positive results indicated that a yellower color acquired.

**-Statistical analysis**

All data obtained for 6 groups were compared using Kruskal-Wallis test. Paired comparisons were performed after significant Kruskal-Wallis test results were found. The degree of association between two variables were evaluated with Spearman's rank correlation coefficient (ρ). The level of statistical significance is $P < 0.05$.

**Results**

L*a*b* values from both color measurements and obtained ΔL*, Δa*, Δb*, and ΔE results for the groups CN, VN, and FN were given in the Table 1.

**Table 1.** Color measurement results of CN, VN, and FN before and after bleaching.

| | $L^*_1$ | $a^*_1$ | $b^*_1$ | $L^*_2$ | $a^*_2$ | $b^*_2$ | ΔL* | Δa* | Δb* | ΔE |
|---|---|---|---|---|---|---|---|---|---|---|
| **CN** | | | | | | | | | | |
| 1 | 72,41 | -1,57 | 16,34 | 69,73 | -1,4 | 13,64 | 2,68 | -0,17 | 2,7 | 3,8 |
| 2 | 72,5 | -1,37 | 14,4 | 69,49 | -1,18 | 11,7 | 3,01 | -0,19 | 2,7 | 4,05 |
| 3 | 74,05 | -1,19 | 14,91 | 70,3 | -1,08 | 12,12 | 3,75 | -0,11 | 2,79 | 4,67 |
| 4 | 75,68 | -0,28 | 12,92 | 72,3 | -0,31 | 10,84 | 3,38 | 0,03 | 2,08 | 3,97 |
| 5 | 73,04 | -0,46 | 15,61 | 70,38 | -0,49 | 13 | 2,66 | 0,03 | 2,61 | 3,72 |
| 6 | 72,64 | -0,23 | 15,1 | 69,68 | -0,31 | 12,49 | 2,96 | 0,08 | 2,61 | 3,92 |
| 7 | 74,07 | -1,05 | 14,53 | 70,8 | -0,93 | 11,85 | 3,27 | -0,12 | 2,68 | 4,21 |
| 8 | 73,84 | -0,72 | 16,36 | 70,75 | -0,7 | 13,55 | 3,09 | -0,02 | 2,81 | 4,18 |
| 9 | 76,17 | -1,25 | 10,77 | 73,5 | -1,13 | 8 | 2,67 | -0,12 | 2,77 | 4,07 |
| 10 | 71,03 | -0,8 | 15,61 | 68,5 | -0,72 | 12,5 | 2,53 | -0,08 | 3,11 | 4 |
| **FN** | | | | | | | | | | |
| 1 | 62,3 | -0,88 | 6,52 | 58,7 | -0,91 | 6,51 | 3,6 | 0,03 | 0,01 | 4,07 |
| 2 | 61,19 | -0,93 | 8,76 | 58,3 | -0,92 | 6,52 | 2,89 | -0,01 | 2,24 | 3,65 |
| 3 | 62,72 | -1,24 | 14,03 | 59,43 | -1,21 | 10 | 3,29 | -0,03 | 4,03 | 5,2 |
| 4 | 60,23 | -0,99 | 11,3 | 58 | -0,9 | 8,23 | 2,23 | -0,9 | 3,07 | 3,79 |
| 5 | 62,09 | -0,28 | 9,02 | 59,36 | -0,76 | 6,5 | 2,73 | -0,02 | 2,52 | 3,71 |
| 6 | 60,98 | -0,66 | 8,07 | 58 | -0,83 | 5,6 | 2,98 | 0,17 | 2,47 | 3,87 |
| 7 | 61,81 | -0,84 | 8,15 | 59,03 | -0,83 | 5,59 | 2,78 | -0,01 | 2,56 | 3,77 |
| 8 | 63,71 | -1,2 | 9,74 | 59,8 | -1,1 | 6,3 | 3,91 | -0,1 | 3,44 | 5,21 |
| 9 | 61,24 | -0,72 | 10,15 | 58,09 | -0,83 | 7,2 | 3,15 | 0,11 | 2,95 | 4,32 |
| 10 | 60,44 | -0,96 | 10,85 | 58 | -0,98 | 8 | 2,44 | 0,02 | 2,85 | 3,75 |
| **VN** | | | | | | | | | | |
| 1 | 71,63 | 1,84 | 17,98 | 68,6 | 1,48 | 15,38 | 3,03 | 0,36 | 2,6 | 4 |
| 2 | 73,17 | 2,02 | 17,91 | 70,04 | 1,65 | 15,26 | 2,77 | 0,37 | 2,65 | 3,86 |
| 3 | 74,46 | 2,08 | 18,74 | 71,74 | 1,83 | 16,25 | 2,72 | 0,25 | 2,49 | 3,7 |
| 4 | 74,26 | 2,05 | 14,85 | 71,2 | 1,68 | 12,8 | 3,06 | 0,37 | 2,05 | 4,01 |
| 5 | 73,99 | 2,46 | 20,58 | 71,18 | 2,13 | 17,88 | 2,81 | 0,33 | 2,7 | 3,38 |
| 6 | 69,19 | 1,85 | 19,04 | 66,4 | 1,55 | 15,76 | 2,79 | 0,3 | 3,28 | 4,3 |
| 7 | 73,68 | 1,76 | 19,32 | 70,69 | 1,53 | 16,68 | 2,99 | 0,23 | 2,64 | 4 |
| 8 | 70,46 | 2,21 | 20,18 | 67,63 | 1,87 | 17,5 | 2,83 | 0,34 | 2,68 | 3,9 |
| 9 | 73,78 | 2,21 | 18,05 | 70,96 | 1,85 | 15,5 | 2,82 | 0,36 | 2,55 | 3,8 |
| 10 | 72,33 | 2,23 | 18,8 | 70,98 | 1,8 | 15,48 | 1,35 | 0,43 | 3,32 | 3,61 |

L*a*b* values from both color measurements and obtained ΔL*, Δa*, Δb*, and ΔE results for the groups CR, VR, and FR were given in the Table 2.

**Table 2.** Color measurement results of CR, VR, and FR before and after bleaching.

| | $L^*_1$ | $a^*_1$ | $b^*_1$ | $L^*_2$ | $a^*_2$ | $b^*_2$ | ΔL* | Δa* | Δb* | ΔE |
|---|---|---|---|---|---|---|---|---|---|---|
| **CR** | | | | | | | | | | |
| 1 | 77,24 | -0,92 | 13,05 | 73,4 | -0,9 | 11 | 3,84 | -0,02 | 2,05 | 4,32 |
| 2 | 75,54 | -0,33 | 13,44 | 71,7 | -0,33 | 10,7 | 3,84 | 0 | 2,74 | 5,2 |
| 3 | 74,43 | -1,15 | 15,78 | 70,2 | -1 | 12 | 4,23 | -0,15 | 3,78 | 5,05 |
| 4 | 76,13 | -0,98 | 11,5 | 71,91 | -0,9 | 9,33 | 4,22 | -0,08 | 2,17 | 4,74 |
| 5 | 72,81 | -1,17 | 16,2 | 68,7 | -1 | 12,35 | 4,11 | -0,17 | 3,85 | 5,6 |
| 6 | 71,31 | -0,41 | 17,27 | 68,53 | -0,35 | 13,65 | 2,78 | -0,06 | 3,62 | 4,56 |
| 7 | 74,67 | -1,31 | 15,52 | 71,7 | -1,11 | 12,85 | 2,97 | -0,2 | 2,67 | 4 |
| 8 | 74,83 | -0,99 | 14,23 | 71,2 | -0,88 | 11,57 | 3,63 | -0,11 | 2,66 | 4,49 |
| 9 | 72,86 | -1,38 | 12,88 | 69,4 | -1,26 | 10,15 | 3,46 | -0,12 | 2,73 | 4,4 |
| 10 | 76,61 | -0,81 | 14,3 | 72,15 | -0,88 | 11,7 | 4,46 | 0,07 | 2,6 | 5,15 |
| **FR** | | | | | | | | | | |
| 1 | 60,92 | -0,96 | 7,76 | 58,4 | -0,9 | 5,01 | 2,52 | -0,06 | 2,75 | 3,8 |
| 2 | 60,97 | -0,94 | 9,99 | 58,5 | -0,88 | 7,07 | 2,47 | -0,06 | 2,92 | 4,05 |
| 3 | 61,56 | -0,91 | 11,04 | 59,35 | -0,95 | 7,92 | 2,21 | 0,04 | 3,12 | 4,67 |
| 4 | 61,97 | -1 | 9,21 | 59,33 | -0,94 | 6,4 | 2,64 | -0,06 | 2,81 | 3,97 |
| 5 | 61,81 | -1,01 | 11,2 | 58,92 | -1,01 | 8,23 | 2,89 | 0 | 2,97 | 3,72 |
| 6 | 61,18 | -0,68 | 9,21 | 57,92 | -0,83 | 6,5 | 3,26 | 0,15 | 2,71 | 3,92 |
| 7 | 60,28 | -0,8 | 9,48 | 57,65 | -0,74 | 7,02 | 2,63 | -0,06 | 2,46 | 4,21 |
| 8 | 60,19 | -0,95 | 10,76 | 57,43 | -0,9 | 8 | 2,76 | -0,05 | 2,76 | 4,18 |
| 9 | 61,88 | -0,74 | 8,73 | 58,95 | -0,84 | 5,99 | 2,93 | 0,1 | 2,74 | 4,07 |
| 10 | 62,95 | -0,86 | 10,77 | 60,45 | -0,93 | 7,62 | 2,5 | 0,07 | 3,15 | 4 |
| **VR** | | | | | | | | | | |
| 1 | 74,61 | 2,15 | 16,5 | 71,9 | 1,78 | 14 | 2,71 | 0,37 | 2,5 | 3,7 |
| 2 | 73,17 | 1,99 | 18,35 | 70,58 | 1,7 | 15,37 | 2,59 | 0,29 | 2,98 | 3,95 |
| 3 | 70,65 | 1,79 | 19,28 | 68 | 1,45 | 17 | 2,65 | 0,34 | 2,28 | 3,5 |
| 4 | 72,33 | 2,04 | 19,55 | 69,45 | 1,76 | 17,13 | 2,88 | 0,28 | 2,42 | 3,76 |
| 5 | 71,74 | 1,66 | 18,56 | 68,38 | 1,44 | 16,18 | 3,36 | 0,22 | 2,38 | 3,64 |
| 6 | 73,89 | 2,09 | 17,01 | 71,74 | 1,73 | 14,8 | 2,75 | 0,36 | 2,21 | 3,54 |
| 7 | 73,55 | 1,92 | 19,4 | 70,49 | 1,64 | 16,8 | 3,06 | 0,28 | 2,6 | 4,02 |
| 8 | 72,79 | 1,52 | 15,04 | 69,5 | 1,14 | 14 | 3,29 | 0,38 | 1,04 | 3,95 |
| 9 | 74,18 | 2,06 | 16,65 | 71,48 | 1,7 | 14 | 2,7 | 0,36 | 2,65 | 3,8 |
| 10 | 70,85 | 2,62 | 21,85 | 68,8 | 2,16 | 18,65 | 2,05 | 0,46 | 3,2 | 3,82 |

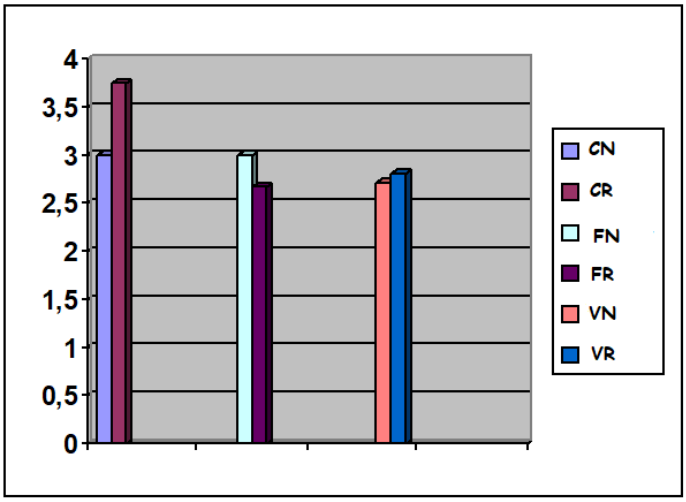
Descriptive statistical analysis results of ΔL* value obtained after 1st and 2nd color measurements of the 6 sample groups were given in the Table 3.

**Table 3.** Descriptive statistical analysis results of ΔL* of the 6 groups.

| | n | Mean | Standard Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| CN | 10 | 3 | 0,1219 | 2,53 | 3,75 |
| CR | 10 | 3,7540 | 0,1748 | 2,78 | 4,46 |
| FN | 10 | 3 | 0,1611 | 2,23 | 3,91 |
| FR | 10 | 2,6810 | 0,09289 | 2,21 | 3,26 |
| VN | 10 | 2,7170 | 0,1563 | 1,35 | 3,06 |
| VR | 10 | 2,8040 | 0,1191 | 2,05 | 3,36 |

Comparison of the ΔL values of CN, CR, FN, FR, VN, and VR groups as pairs using the Kruskal-Wallis test revealed that the differences were statistically non-significant ( $P > 0.05$). The highest ΔL result was measured from CR samples whereas, ΔLs from FR group were found to be the lowest among all samples. The graphic of the distribution of the mean values of ΔL between the 6 groups was given in the Figure 4.

**Figure 4.** Distribution of the mean values of ΔL between the 6 groups.



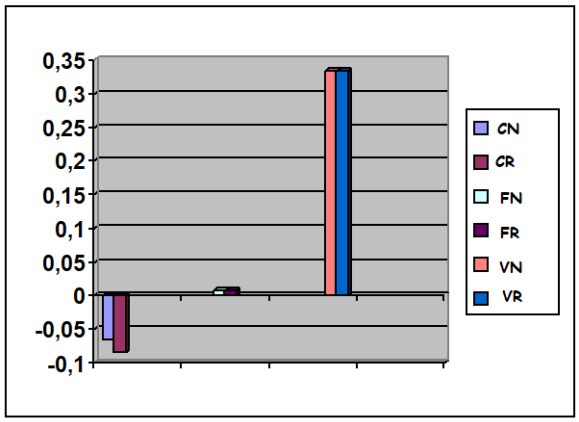

Descriptive statistical analysis results of Δa* values of the 6 groups were given in the Table 4.

**Table 4.** Descriptive analysis results of Δa* values of the 6 groups.

| | **Δa*** | | | | |
|---|---|---|---|---|---|
| | **N** | **Mean** | **Standard Deviation** | **Minimum** | **Maximum** |
| CN | 10 | -0,0670 | 0,02906 | -0,19 | 0,08 |
| CR | 10 | -0,0840 | 0,02638 | -0,20 | 0,07 |
| FN | 10 | 0,007 | 0,02612 | -0,10 | 0,17 |
| FR | 10 | 0,007 | 0,02481 | -0,06 | 0,15 |
| VN | 10 | 0,3340 | 0,01893 | 0,23 | 0,43 |
| VR | 10 | 0,3340 | 0,02146 | 0,22 | 0,46 |

The Δa* values of the samples compared as pairs with the Kruskal-Wallis test. No significance was found between the groups ($p>0.05$). The highest Δa* value was recorded in VN, and the lowest in CR. The graphic of the distribution of the mean values of Δa* between the 6 groups was given in the Figure 5.

**Figure 5.** Distribution of the mean values of Δa* between the 6 groups.



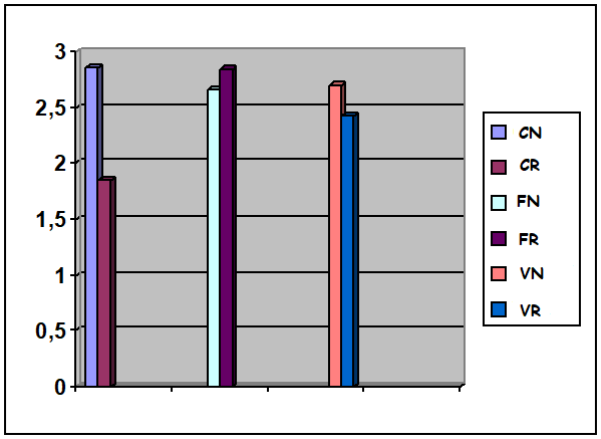

Descriptive statistical analysis results of Δb* values of the 6 groups were given in the Table 5.

**Table 5**. Descriptive analysis results of Δb* values of the 6 groups.

| | Δb* | | | | |
|---|---|---|---|---|---|
| | **N** | **Mean** | **Standars Deviation** | **Minimum** | **Maximum** |
| CN | 10 | 2,6860 | 0,08112 | 2,08 | 3,11 |
| CR | 10 | 1,8520 | 1,1302 | -8,18 | 3,85 |
| FN | 10 | 2,6140 | 0,3336 | 0,01 | 4,03 |
| FR | 10 | 2,8390 | 0,0636 | 2,46 | 3,15 |
| VN | 10 | 2,6960 | 0,1167 | 2,05 | 3,32 |
| VR | 10 | 2,4260 | 0,1821 | 1,04 | 3,20 |

Comparison of the Δb* values of CN, CR, FN, FR, VN, and VR groups as pairs using the Kruskal-Wallis test revealed that the differences were statistically non-significant ($p>0.05$). The highest Δb* value was recorded in FR, and the lowest in CR. The graphic of the distribution of the mean values of Δb* between the 6 groups was given in the Figure 6.

**Figure 6.** Distribution of the mean values of Δb* between the 6 groups.



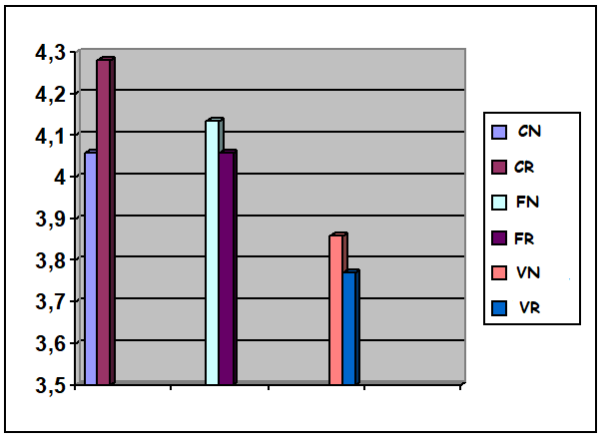
Descriptive statistical analysis results of ΔE values of the 6 groups were given in the Table 6.

**Table 6.** Descriptive analysis results of ΔE values of the 6 groups.

| | ΔE | | | | |
|---|---|---|---|---|---|
| | **N** | **Mean** | **Standard Deviation** | **Minimum** | **Maximum** |
| CN | 10 | 4,0590 | 0,08325 | 3,72 | 4,67 |
| CR | 10 | 4,2830 | 0,04429 | 0,52 | 5,60 |
| FN | 10 | 4,1340 | 0,01890 | 3,65 | 5,21 |
| FR | 10 | 4,0590 | 0,08325 | 3,72 | 4,67 |
| VN | 10 | 3,8560 | 0,08020 | 3,38 | 4,30 |
| VR | 10 | 3,7680 | 0,05561 | 3,50 | 4,02 |

The ΔE values of the samples compared as pairs with the Kruskal-Wallis test. No significance was found between FR-FN, and VN-VR comparisons ($P = 0.1$, $P = 0.3$ respectively). However, ΔE comparison in the CN-CR pair revealed statistically significant difference ($P = 0.001$). The highest Δa* value was recorded in VN, and the lowest in CR. The graphic of the distribution of the mean values of ΔE between the 6 groups was given in the Figure 7.

**Figure 7.** Distribution of the mean values of ΔE between the 6 groups.




## Discussion

The null hypothesis of the study is rejected due to the significant difference found between the ΔE values of CN and CR groups.

The effect of bleaching procedure on tooth was reported to be caused by the agent's penetration into enamel, degrading of the chromogens, and the change of the reflection characteristic of light due to the alteration of the surface properties.[10,19] At the end of this complex

mechanism of action, bleaching lightens the tooth color.[10] The symbol for the lightness feature of light in CIEL*a*b* color system is L*.[9] If an object absorbs all the incident light without reflecting, the L* value would be 0 and the object would be darkest. If an object reflects light completely then it would be the ligthest and the L* value would be measured 100.[9] None of the ceramic samples became lighter following the bleaching in the present study. This could be be explained by the structural differences between ceramic and enamel. Whereas dental ceramics are completely inorganic, enamel includes organic component which constitute the matrix of the structure.[22]

Tooth surface can adsorbe limited amount of bleaching agent owing to the prismatic nature of enamel. Existence of agents in dentinoenamel junction, dentine and even pulp chamber after 5 to 15 minute bleaching sessions was reported by previous researches.[17,19-22] The cause of the unexpected change in ΔL* values is thought to be the lack of the chromogen accumulation on none of the samples in this study. Therefore the research design is quite different from the in vivo studies that evaluated color previously.

Although mean values of Δa* of the CR and CN groups altered negatively, the change was found to be minimal. However, it is not possible to state that the samples would appear greener. The change in the Δa* values measured for FN and FR samples was positive, yet its amount was even less than the CR-CN pair. The greatest but statistically insignificant alteration of Δa* value was obtained in VN/ VR groups' measurements and it can be notified that the samples look redder after bleaching. Nevertheless, a previous study reported that Δa* values did not have a strong correlation with ΔE which indicates total color change less the direction of it.[23]

Δb* of all groups were found positive much greater than the ΔL* ve Δa* values. Therefore, it is posssible to state that all samples were yellower following the bleaching procedure. Although, this finding was parallel to the study of Ishikawa-Nagai et al[23] and the change in b* values showed a stronger correlation compared to Δa*, it has to be kept in mind that the increase in b* values was statistically insignificant.

The mean ΔE values of all 6 groups were calculated between 3.7 and 4.2. The highest score was in CR group which was followed by FN, FR, CR, VN, VR respectively. However, the only significant ΔE was recorded in the comparison of CN- CR groups ($P$ = 0.001). For human visual perception to detect a difference in color of two objects, ΔE has to be over a

certain threshold on which no consensus was reached[6]. The highest needed ΔE value for recognition of color difference was reported to be 3.7 and the lowest 1.[6] Thus, all the ΔE scores recorded in the present study were over this highest value, it is possible to state that bleaching procedure effects the color of porcelain restorations as human eye can detect.

There are some limitations of this study. The most important one is thought to be the inclusion of a single bleaching agent, only carbamide peroxide was used in the study. Another limitation is the lack of a method to ensure a standard glaze layer thickness. Being the first to encounter with the bleaching agent, the thickness and uniformity of this layer are crucial factors that can affect the outcomes of the research.

## Conclusion

Consequently, vital bleaching procedure have the potential to effect the color features of feldspathic dental ceramics.

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