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## Research Article

# Effect of Different Surface Finishing Procedures on Color Stability of Leucite-reinforced Feldspathic CAD-CAM Ceramic

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# Effect of Different Surface Finishing Procedures on Color Stability of Leucite-reinforced Feldspathic CAD-CAM Ceramic

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## Abstract

**Statement of the problem:** The color stability of newly introduced leucite-reinforced feldspathic CAD-CAM ceramic with different surface treatments remains unclear.

**Objective**: This in-vitro study aimed to examine the effect of different surface finishing procedures on the color stability of leucite-reinforced feldspathic CAD-CAM ceramic.

**Materials & Methods:** Twenty-four monochromatic, leucite-reinforced, A2-shaded feldspathic ceramic specimens prepared in 1 mm thickness. The specimens were randomly divided into 3 groups according to their surface finishing methods (n=8): a control group without surface finishing (Group C), surface finishing with polishing discs (Sof-Lex, 3M ESPE), and surface finishing with glaze (Group G). All the specimens were immersed in a coffee solution and kept in an incubator at 37 °C for 14 days. Initial color measurements were made with a digital spectrophotometer and the Commission Internationale de l'Eclairage (CIE) L*a*b* values were recorded. The color measurements were repeated at the ends of the 1st, 3rd, 7th, and 14th days with the spectrophotometer under the same conditions. The color change of the specimens was calculated with the CIEDE2000 (ΔE00) formula. Statistical analysis of the data was performed with a two-way mixed ANOVA and Bonferroni post-hoc tests ($\alpha$=0.05).

**Results:** Time and surface finishing procedures caused statistically significant color changes in the specimens (P<0.05). However, the interaction of time and surface finishing was not statistically significant (P>0.05). The lowest mean ΔE00 value was observed in Group G on day 14 (0.93 ± 0.74); the highest mean ΔE00 value was found in Group P on the 3rd and 14th days (2.16 ± 0.72). While the C and G groups exhibited similar color change values, Group P caused higher ΔE00 values compared to the glaze application (P<0.05).

**Conclusions:** Based on the findings of this study, glaze application led to less color change compared with disk polishing. Glazing can be preferred to polishing to ensure long-term color stability in leucite-reinforced feldspathic ceramics.


**Keywords:** Color Stability, Surface Finishing, Polishing, Glaze, Ceramic, CAD-CAM

## Introduction

Due to their biocompatibility, chemical stability, reduced plaque accumulation, and superior esthetic features, dental ceramics are routinely used in dentistry.[1,2] With the increasing demand for esthetics, ceramic systems produced with computer-aided design and computer-aided manufacturing (CAM-CAM) have been developed and widely used.[3] Leucite-reinforced feldspathic ceramic is one of the types of ceramics that can be produced with CAD-CAM systems.[4] The existence and size of leucite crystals determine physical strength, and increasing the size of the crystals enhances the material's strength.[5] Furthermore, leucite-reinforced feldspathic ceramics have superior esthetic properties.[5] These ceramics have been used for inlays, onlays, laminate veneers, and anterior and posterior single-unit crowns.[6,7] G-Ceram glass-ceramic block (Atlas Enta, Gülşa, İzmir, Turkey) was introduced as a leucite-reinforced feldspathic monochromatic CAD-CAM ceramic block. These blocks are generated as a consequence of controlled crystallization in the glass phase as a result of various thermal procedures used and have excellent strength due to the homogeneous expansion of leucite crystals nucleated in the glass phase via incremental heat treatment according to the manufacturer.

Despite their favorable characteristics, dental ceramics require finishing and polishing techniques to provide the desired surface texture and light reflection. Traditionally, glazes are used to finish the surface of ceramics.[8] However, dentists are sometimes required to remove the superficial glaze layer from ceramic restorations using diamond burs. These applications are necessary when there is premature occlusal contact, for the arrangement of erroneous contours, following esthetic requirements, and sometimes per the patient's request.[8,9] Some occlusal modifications also should be made following cementation, especially when using adhesive cemented ceramic restorations.[10]

Removing the glaze layer increases the surface roughness. For this reason, the researchers recommended re-glazing or polishing to obtain surface smoothness.[11,12] Some authors stated that the smooth surface of CAD-CAM ceramics depends on the different surface finishing methods such as glaze and polishing systems. Also, they reported that polishing could be an alternative treatment procedure to glazing.[13-15] Lots of polishing systems are used in dentistry including abrasive rubber discs, diamond or tungsten carbide burs, silicone rubber discs, and aluminum oxide-coated abrasive discs.[16,17]

To obtain an esthetic rehabilitation that is consistent with natural teeth, ceramic restorations should have similar optical properties to natural teeth, such as color, translucency, fluorescence, and opalescence.[18] The problem with esthetic restorations is an inability to achieve color harmony with natural teeth and long-term color stability.[13] The color stability of restorative materials can be affected by plaque accumulation, chemical degradation, surface texture, and coloration caused by nutrition.[17, 19] The diet, immersion time, and porcelain surface texture can cause the discoloration of the prosthetic materials.[15] Beverages such as tea, coffee, and cherry juice contain colorants and these coloring ingredients can cause discoloration of the restoration and negatively affect its aesthetics.[20]

There are various studies about the color stability of CAD-CAM ceramics in the literature.[15, 21-24] However, to the authors' knowledge, there is no study about the color stability of newly introduced leucite-reinforced CAD-CAM ceramic with different surface finishing procedures. This study aimed to evaluate the effect of different surface finishing procedures on the color stability of leucite-reinforced feldspathic CAD-CAM ceramic. The null hypothesis of the study was that the color stability of the leucite-reinforced CAD-CAM ceramic will not be affected by the surface finishing procedures.

## Materials & Methods

A CAD-CAM leucite-reinforced feldspathic ceramic block (G-Ceram, Atlas Enta, Gülşa, İzmir, Turkey) was used in this study. All blocks were selected in A2 color for standardization. The blocks were cut with a low-speed diamond saw (DIMOS ø1.25 mm, Metkon, Turkey) under water cooling. A total of 24 specimens were obtained with a final thickness of 1.0 ± 0.1 mm. Each specimen was pre-polished using silicon carbide papers (Grids 600, 800, 1000, and 1200; English Abrasive and Chemicals Ltd., Stafford, USA) under cooling water. The thickness of each specimen was measured with a digital caliper (Asimeto, TESA, France).

The specimens were randomly divided into 3 groups according to their surface finishing methods (n=8): control group without surface finishing (Group C), surface finishing with polishing discs (Sof-Lex, 3M ESPE, St Paul, MN, USA) (Group S) and surface finishing with glaze (Group G). The specimen surfaces were polished with polishing discs (Sof-Lex; 3M/ESPE, USA) by a single operator for 30 seconds with medium, fine and superfine discs, with an electric low-speed handpiece set (AM 25 BC, W&H, Bürmoos, Austria) respectively. Glaze (Ceramco, Dentsply Sirona, USA) was applied to one surface of the specimens with a brush according to the manufacturer's instructions. After the application, the specimens were furnaced

in a ceramic furnace (Programat P310, Ivoclar Vivadent, Schaan, Liechtenstein) at 895°C following the manufacturer's recommendations.

Color coordinates of the specimens were measured under the D65 standard illumination. Before each measurement, the spectrophotometer was calibrated following the manufacturer's instructions. For the initial color measurements, the Commission Internationale de l´Eclairage (CIE) L*a*b* values for all the specimens were measured with a digital spectrophotometer (Easyshade V, Vita Zahnfabrik, Bad Säckingen, Germany) on a neutral gray background for three times and average values were recorded. The coffee solution was prepared with 2 gr of coffee (Nescafe Classic; Nestle, Vevey, Switzerland) and 200 ml of boiled water according to the manufacturer's recommendation. Each specimen was kept in an incubator at 37 °C with separate bottles containing 10 ml of coffee solution. The coffee solutions were renewed every 24 hours. Before the measurement, all specimens were gently washed and rinsed with an air-water spray. Color measurements were repeated at the end of the 1st, 3rd, 7th, and 14th days with the spectrophotometer under the same conditions the color change of the specimens between the initial measurement and each day were calculated with the CIEDE2000 ($\Delta E_{00}$) formula:[25]

$$\Delta E_{00} = \left[\left(\frac{\Delta L'}{K_L S_L}\right)^2 + \left(\frac{\Delta C'}{K_C S_C}\right)^2 + \left(\frac{\Delta H'}{K_H S_H}\right)^2 + R_T\left(\frac{\Delta C'}{K_C S_C}\right)\left(\frac{\Delta H'}{K_H S_H}\right)\right]^{1/2}$$

The parametric factors $K_L$, $K_C$, and $K_H$ were all set to 1 as previously mentioned.[21] Based on the research of Paravina et al.[26], a $\Delta E_{00}$ 50% perceptibility threshold of 0.8 units and a 50% acceptability threshold of 1.8 units were accepted for this study.

A software program (SPSS v26, IBM Corp., USA) was used for statistical analyses. Normality was assessed with the Shapiro-Wilk test. Two-way mixed ANOVA and Bonferroni post-hoc tests were used to analyze the results ($P<0.05$).

**Results**

Table 1 presents the two-way mixed ANOVA results and Table 2 shows the means and standard deviations for the $\Delta E_{00}$ values of the groups. The main effects of the surface finishing procedures and time caused statistically significant color changes in the specimens ($P<0.05$). However, the interaction of surface finishing procedures and time was not statistically significant ($P>0.05$) (Table 1). Regardless of the time, the glazing process exhibited a significantly lower mean $\Delta E_{00}$ value than other surface finishing procedures. However, the polishing application caused the highest mean $\Delta E_{00}$ value, and showed a similar color change with Group C.

Regardless of the surface finishing procedures, the highest mean $\Delta E_{00}$ value was obtained on the 7th day, however, there was no statistical difference among 3rd, 7th and 14th days (P>0.05).

**Table 1.** Two-way mixed ANOVA results.

| Source | Type III Sum of Squares | df | F | P | Partial Eta Squared |
|---|---|---|---|---|---|
| Time | 2.534 | 3 | 6.755 | 0.001 | 0.243 |
| Treatment | 15.972 | 2 | 5.057 | 0.016 | 0.325 |
| Time x Treatment | 1.413 | 6 | .235 | 1.883 | 0.098 |

All the groups showed $\Delta E_{00}$ values above the perceptibility threshold (>0.8); however, except the Group P, Group C and G showed $\Delta E_{00}$ values below the acceptability threshold in each time point (<1.8) The highest mean $\Delta E_{00}$ value was found in Group P on the 3rd (2.16 ± 0.65) and 14th days (2.16 ± 0.72) and the lowest mean $\Delta E_{00}$ value was observed in Group G at day 14 (0.93 ± 0.74) (Table 2).

**Table 2.** Means and standard deviations of groups for $\Delta E_{00}$.

| Surface Treatment | Color Change ($\Delta E_{00}$) | | | | TOTAL |
|---|---|---|---|---|---|
| | 1st Day | 3rd Day | 7th Day | 14th Day | |
| Control (Group C) | 1 ± 0.43 | 1.27 ± 0.53 | 1.57 ± 0.62 | 1.50 ± 0.49 | $1.33^{AB}$ |
| Sof-Lex (Group S) | 1.81 ± 0.58 | 2.16 ± 0.65 | 2.13 ± 0.60 | 2.16 ± 0.72 | $2.07^{B}$ |
| Glaze (Group G) | 1.03 ± 0.71 | 0.99 ± 0.72 | 1.50 ± 1.25 | 0.93 ± 0.74 | $1.11^{A}$ |
| TOTAL | $1.28 \pm 0.67^{a}$ | $1.47 \pm 0.80^{b}$ | $1.74 \pm 0.89^{b}$ | $1.53 \pm 0.81^{ab}$ | |

Different superscript uppercase letters indicate significant differences among groups for each column within each parameter (P<0.05). Different superscript lowercase letters indicate significant differences among groups for each row (P<0.05).

## Discussion

This study evaluated the color stability of the leucite-reinforced CAD-CAM glass-ceramic with different surface finishing procedures. According to the results, the effect of surface finishing treatments and time on color change was found to be statistically significant, therefore the null hypothesis of the study was rejected.

The studies which investigated the color stability of CAD-CAM ceramics, thicknesses ranging from 1 mm to 2 mm were mostly preferred.[14,22,27] According to some studies, the A2

shade is one of the most common shades found in certain populations[28,29] and has been frequently preferred in studies examining the optical properties of ceramic materials.[30-32] Therefore, 1 mm thickness and an A2-shaded specimens were used in this study.

Manual polishing, glaze, and manual polishing with polishing pastes are mostly preferred as surface finishing treatments.[23] Sometimes readjustment is necessary for correcting the occlusal interferences and esthetic improvements after the cementation. With the readjustment, the glaze layer was removed from the super facial layer. To minimize surface roughness and color change, various polishing systems could be used instead of glaze.[13-15] In this study, glaze and manual polishing processes were used as surface finishing treatments.

Al Alahmari[33] has reported that the dipping time in the solution can affect the amount of color change. In studies on color stability, tea, coffee, cherry juice, and wine are often preferred as dipping solutions.[34-36] In this study, coffee, one of the most consumed beverages in the world, was preferred. It has been stated that coffee consumers consume 3.2 cups of coffee a day and the average time to drink 1 cup of coffee is 15 minutes. The dipping time in the beverages for 24 hours in solution is the 1 monthly coffee consumption period of the consumers.[37] In this study, the specimens were kept in solutions for 14 days. This period is equivalent to 14 months of coffee consumption.[22,38]

In many studies, it has been stated that the CIEDE2000 ($\Delta E_{00}$) formula is more sensitive and reliable than the CIE L*a*b* formula in determining the color difference.[17] According to the literature CIEDE2000 formula was used in this study. Studies using the CIEDE2000 formula used the color difference thresholds of the study of Paravina et al.[26] as a reference. [21, 39] According to the CIEDE2000 formula, the perceptibility threshold was determined as $\Delta E_{00} < 0.8$, and the acceptability threshold was determined as $\Delta E_{00} < 1.8$. Except for Group S, the color change of all material groups was in the visually perceptible threshold value ($1<\Delta E_{00}<1.4$). At the end of the 14th day, the $\Delta E_{00}$ value for Group S was obtained as 2.1 and this value exceeds the perceptible threshold value ($\Delta E_{00}<1.8$).

There are many types and brands of polishing kits recommended for CAD-CAM ceramics on the market. Sof-Lex polishing discs are one of the most used polishing systems.[40, 41] Akar et al.[23] reported that the surface finishing treatments affect the surface roughness and therefore the color stability in their study. They stated that the smoothest surfaces were obtained in the glazed groups and also ΔE values were significantly lower than in the polishing group. Similarly, the glaze application led to the lowest color change in the present study. Because, as

reported in previous studies, the coloration increases as the surface roughness increases.[3, 19, 22] Although surface roughness was not investigated in this study, the lower $\Delta E_{00}$ values can be attributed to the smooth surface of the glazed specimens.

Sarikaya et al.[24] investigated the effects of different surface treatments (no surface treatment, polishing, and glaze) on the color stability of various dental ceramics (Vita VMK 95, Ceramco III, Matchmaker, and Vitablocs Mark II). At the end of 48 hours, the color change values of the specimens kept in the coffee solution were compared. They reported that the glazed specimens showed less color change than polished with Sof-Lex discs. Similar to Sarikaya et al.'s study, glazed specimens have higher color stability than polished specimens in this study.

Alp et al.[21] evaluated the effects of surface finishing treatments applied to monolithic CAD-CAM glass ceramics on color change after coffee thermocycling. They stated that only material type (microstructure) significantly affects the color difference. The surface finishing protocols did not affect the color change. Contrary to the study of Alp et al.,[21] the effect of surface finishing procedures on color change was found to be statistically significant in this study. This discrepancy could be attributed to the different materials used in the studies as well as the usage of a different polishing kit.

Aldosari et al.[14] applied different surface treatments (glaze and polishing) to different ceramics (hybrid ceramics, feldspathic ceramics, and zirconia-reinforced lithium silicate) and evaluated the ΔE values after Arabic coffee thermal cycling. When the ΔE values of the feldspathic ceramics were evaluated, it was found that the ΔE value of the glazed specimens was lower than the polished ones; however, they reported that this difference between the applications was not statistically significant.[14] In this study, similar to the study of Aldosari et al.,[14] the polished specimens showed lower color stability. However, the difference between the ΔE values of the polished and glazed specimens was statistically significant in this study. This difference may be due to the use of different materials, solutions, varied exposure time to solutions, and study designs.

There are some limitations in this study. This in-vitro study did not reflect the intraoral environment. Only one type of ceramic was evaluated and one type of polishing set was used for the surface finishing treatment and no comparison could be made with different polishing discs and pastes. Although there are many coloring beverages, only the effect of coffee on color change has been studied. Therefore further in vitro and in vivo studies are needed.

## Conclusion

Within the limitations of this study, it can be concluded that the surface finishing procedures significantly affect color stability. Glaze application caused less color change than polishing with discs. In the polishing group, significant mean color differences were observed, and these values exceeded the acceptable color threshold value. For long-term color stability, the leucite-reinforced feldspathic ceramics glaze can be preferred to polishing with polishing discs.

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