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Evaluation of the Effect of Different Finishing and Polishing Procedures on the Color Change and Translucency Properties of Monolithic CAD/CAM Ceramic

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ABSTRACT

Aim: The purpose of this study was to compare the effects of different finishing and polishing procedures for monolithic CAD/CAM ceramics on their optical properties after ultraviolet (UV) aging.
Material and Methods: A zirconia-reinforced lithium silicate ceramic (Vita Suprinity) with a thickness of 1.5 mm was selected for this study. A total of 42 samples were prepared and divided randomly into six groups on the basis of the finishing–polishing technique used: disc, polishing paste and glazing or combinations (n=7). Color change measurements of the samples were performed on a gray background before and after UV aging. The translucency values on white and black backgrounds were calculated after UV aging according to the CIEDE2000 formula. The Kruskal–Wallis H test and post hoc Dunn test were used for the statistical analysis (P<0.05).
Results: The effects of finishing–polishing procedures were statistically significant in terms of color change and translucency (P<0.001). The highest color change was found in the crystallized samples. The samples polished with polishing paste after crystallization and glazing exhibited the lowest color change. The lowest translucency was presented in the samples that just crystallized. The highest translucency was presented in ceramics crystallized with glaze, which was significantly different from that in those crystallized, crystallized+polished with discs, and crystallized+polished with polishing paste ceramics (P<0.001).
Conclusion: Finishing ceramic restorations is an important step for long-term clinical use. Glazing or mechanical polishing of zirconia-reinforced lithium silicate ceramics produces similar results in terms of optical properties. Crystallization with glazing together can be used for quick and reliable finishing.

Monolitik CAD/CAM Seramiğin Renk Değişimi ve Yarı Saydamlık Özellikleri Üzerinde Farklı Bitirme ve Polisaj Prosedürlerinin Etkisinin Değerlendirilmesi

Makale Bilgisi

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ÖZET

Amaç: Bu çalışmanın amacı, farklı bitim ve polisaj prosedürlerinin monolitik CAD/CAM seramiğin optik özellikleri üzerindeki etkisini UV yaşlandırma sonrası karşılaştırmaktır.
Gereç ve Yöntemler: Bu çalışma için 1,5 mm kalınlığında zirkonya ile güçlendirilmiş lityum silikat seramik (Vita Suprinity) seçildi. Toplam 42 adet örnek hazırlanarak disk, polisaj pastası, glaze veya kombinasyonları ile bitirme ve cilalama tekniklerine göre rastgele altı gruba ayrıldı (n=7). Örneklerin renk değişimi ölçümleri, UV yaşlandırma öncesi ve sonrası gri bir arka plan üzerinde gerçekleştirildi. Beyaz ve siyah zemin üzerindeki translüsensi değerleri ise UV yaşlandırma sonrası CIEDE2000 formülüne göre hesaplandı. İstatistiksel analizlerde Kruskal–Wallis H ve post hoc Dunn testleri kullanıldı (P<0,05).
Bulgular: Renk değişimi ve translüsensi açısından bitirme ve polisaj prosedürlerinin etkisi istatistiksel olarak anlamlı bulundu (P<0,001). En yüksek renk değişimi yalnızca kristalize örneklerde görüldü. En düşük renk değişimini kristalizasyon ve glaze sonrası polisaj pastası ile polisajlanan örnekler sergiledi. En düşük translüsensi parametrelerini yalnızca kristalize örnekler sundu. En yüksek translüsensi parametreleri glaze ile birlikte kristalize edilen seramiklerde ortaya çıktı ve kristalizasyon, kristalizasyon+disk ile cilalama ve kristalizasyon+parlatma pastası ile cilalama ile karşılaştırıldığında istatistiksel olarak farklılık gösterdi (P<0,001).
Sonuç: Seramik restorasyonların bitirilmesi uzun süreli klinik kullanım için önemli bir adımdır. Zirkonya ile güçlendirilmiş lityum silikat seramiğin glazelenmesi veya mekanik olarak parlatılması, optik özellikler açısından benzer sonuçlar verir. Glaze ile birlikte kristalizasyon, hızlı ve güvenilir bir son işlem olarak kullanılabilir.

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INTRODUCTION

Improvements in monolithic ceramic materials and computer-aided design and computer-aided manufacturing (CAD/CAM) technologies supply to manufacture aesthetic restorations without chipping veneer ceramics in chairside time.[1] One of the high-strength glass ceramics that can be produced monolithic is zirconia-reinforced lithium silicate, which is marketed as monochromatic blanks at two translucency levels.[2] The development of zirconia-reinforced lithium silicate glass ceramics in prefabricated and preprocessed forms has made them suitable for the production of restorations with reduced internal defects through subtractive manufacturing.[3] Zirconia-reinforced lithium silicate ceramics are in an intermediate sintered i.e. pre-crystallized structure for easy milling, and require crystallization firing, in which lithium silicate crystals grow and gain the final color and strength of the ceramic.[3,4] The manufacturer recommends that restorations produced from these blocks be crystallized in a vacuum furnace that allows slow cooling.[2] These ceramics are reported to have better mechanical properties, however higher opalescence and lower translucency when compared to the lithium silicate ceramics probably connected to the material content.[5]

Color and translucency play active roles in matching ceramic restorations with natural appearance and provide aesthetic results.[6] Optical properties depend on several intrinsic characteristics of the material, such as its composition, grain size, porosity and sintering process [7-9], and extrinsic factors, such as surface texture and glaze.[10] Monolithic ceramic restorations, which are fabricated with CAD/CAM, require polishing or glazing to provide smooth and glossy finish after crystallization. Manufacturers recommend both mechanical polishing and/or glazing with glazing spray and pastes for finishing zirconia-reinforced lithium silicate ceramics. Tungsten carbid finishing burs and silicon carbide or rubber polishing discs, with different colors and grain sizes, are used for finishing and glazing protocols.[11,12]

The color and translucency parameters are evaluated with the color coordinates represented in the CIELAB color space. Currently, the CIEDE2000 color difference formula is recommended for standard color change assessment and is also based on CIELAB color coordinates.[13,14] Translucency parameter can be calculated by the difference over white and black backgrounds. While the result is zero in opaque materials, the translucency of the material increases when the result is more than zero.[15]

Previous studies have compared the effects of polishing and finishing methods in CAD/CAM restorations. Kılınç and Turgut [16] reported that mechanical polishing procedures ensured similar optical properties when compared to conventional glazing methods for aesthetic CAD/CAM restorations. Tholt et al. [17] reported that polishing methods had varying effects on three different ceramics that they studied. When the related literature is reviewed, it is not clear which finishing protocol provides the optimum optical appearance for zirconia-reinforced lithium silicate ceramics.

The aim of this in vitro study was to define the color change (ΔE_{00}) and translucency parameter (TP_{00}) of zirconia-reinforced lithium silicate ceramics after different finishing and polishing procedures after ultraviolet (UV) aging. The null hypothesis was that the color change (ΔE_{00}) and translucency parameter (TP_{00}) of the samples are not dependent on different finishing and polishing procedures.

MATERIAL AND METHODS

Power analysis was performed via the G*Power V3.1.9.7 program to determine the number of samples to be included in the study. Considering the results of the opalescence parameters in the reference study [18], a minimum of 18 samples in total should have been included in the study, with 3 samples in each group, as a result of one-way ANOVA power analysis with 95% confidence (1-α), 95% test power (1-β), and an effect size of f=1.702. The study was completed with 42 samples, and the power of the study was 100% as a result of one-way ANOVA post hoc power analysis with 95% confidence (1-α), f=1.702 effect size.

The zirconia-reinforced lithium silicate CAD/CAM ceramic chosen for this study was Vita Suprinity shade A1 (Vita Zahnfabrik, Bad Sackingen, Germany). Rectangular samples (1.5×12×14 mm) were prepared by slicing ceramic blocks of 12×14×18 mm into 1.5 mm thickness with a diamond disc (Microcut, Metkon, Turkey). All dimensions were confirmed to be within 0.1 mm with digital calipers (IP67, Yamer, İzmir, Turkey). In total, 42 ceramic samples were prepared and divided randomly into six groups on the basis of the finishing and polishing procedures (n=7). The materials and manufacturers used for the finishing and polishing methods are presented in Table 1, and the finishing and polishing procedures are defined in Table 2. All crystallization and glazing applications were carried out in a porcelain furnace (Programat P710, Ivoclar Vivadent AG, Schaan Liechtenstein) with the parameters defined by the manufacturer. Additionally, after all procedures, the specimen thicknesses were checked with a digital caliper.

Table 1: Materials used in the study

Materials	Manufacturer
The zirconia-reinforced lithium silicate CAD/CAM ceramic (Vita Suprinity)	Vita Zahnfabrik, Bad Sackingen, Germany
Polishing discs	Vita Suprinity Polishing Set Clinical, Vita Zahnfabrik, Bad Sackingen, Germany
Polishing paste	Renfert Polish, Renfert, Hilzingen, Germany
Glaze material	HeraCeram Glaze Universal, Kulzer, Germany

Table 2: Study design for the finishing and polishing procedures

Groups	Finishing and polishing procedures
(1) Crystallized+polished with discs	Step 1: Crystallized in the porcelain furnace at 830°C/8 min Step 2: Polished with prepolishing pink instruments at 10.000 rpm/60 sec per instruments Step 3: Polished with high-gloss polishing gray instruments at 5.000 rpm/60 sec per instruments
(2) Crystallized+polished with polishing paste	Step 1: Crystallized in the porcelain furnace at 830°C/8 min Step 2: Polished with prepolishing pink instruments at 10.000 rpm/60 sec per instruments Step 3: Polished with high-gloss polishing instruments at 5.000 rpm/60 sec per instruments Step 4: Applied the polishing paste with brush at 60 sec
(3) Crystallized+glazed	Step 1: Crystallized in the porcelain furnace at 830°C/8 min Step 2: Glazed in the porcelain furnace at 800°C/1 min
(4) Crystallized+glazed+polished with polishing paste	Step 1: Crystallized in the porcelain furnace at 830°C/8 min Step 2: Glazed in the porcelain furnace at 800°C/1 min Step 3: Applied the polishing paste with brush at 60 sec
(5) Crystallized with glaze	Step 1: Applied the glaze material Step 2: Crystallized with the glaze material at 830°C/8 min
(6) Control/Crystallized	Step 1: Crystallized in the porcelain furnace at 830°C/8 min

After finishing the polishing procedures, a colorimeter (ShadeEye NCC, Shofu, Kyoto, Japan) was used for color difference measurements of the ceramic samples. Measurements were performed on a gray background under D65 standard illumination before and after UV aging procedures to calculate the color change of the samples. The colorimeter was calibrated, and the samples were cleaned and dried before measurement. During the measurements, first, the colorimeter was placed on the center of the ceramic samples, and L*a*b* values were recorded for each sample. The measurements were then repeated two more times, and the final values were calculated by averaging the three measurements.

The CIEDE2000 formula was used to calculate the color change values of each sample. In the defined formula, variations in lightness, chroma and hue data are expressed as ΔL', ΔC', and ΔH'. SL, SC and SH are weighting functions of chrome and hue. RT is the cycle function that shows the amount of interaction between chroma and hue differences in the blue area in the CIE L*a*b color system. KL, KC and KH are parametric factors calculated for lightness, chroma and hue and are taken as 1.[19]

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

The translucency parameters (TP_{00}) were measured by determining the L*a*b* values against a black and white background after finishing–polishing procedures and UV aging. The CIEDE2000 formula was used to calculate the translucency parameter of each sample. In this formula, the lightness (L), color (C) and hue (H) of the ceramic samples on white and black backgrounds are indicated with the subscripts 'B' and 'W'.[20] All color measurements were performed three times for each ceramic sample, and the final values were calculated by averaging the three measurements.

$$TP_{00} = \left[\left(\frac{\Delta L_{(B-W)}'}{K_L S_L}\right)^2 + \left(\frac{\Delta C_{(B-W)}'}{K_C S_C}\right)^2 + \left(\frac{\Delta H_{(B-W)}'}{K_H S_H}\right)^2 + R_T\left(\frac{\Delta C_{(B-W)}'}{K_C S_C}\right) + \left(\frac{\Delta H_{(B-W)}'}{K_H S_H}\right)\right]^{1/2}$$

UV aging was performed for 27 hours in a test machine (Atlas UV test machine, Illinois, USA) using UVB-313 fluorescent lamps. The light source was applied continuously to the measurement surface of each sample. The temperature of the panels to which the samples were attached was 38°C in the dark and 70°C in the light during water spraying. The humidity rate was 50% in the light and 95% in the dark. The dry lamp temperature was 38°C in the dark and 42°C during the light period. The test procedure was performed as follows: 40 minutes of light only, 20 minutes of light by spraying water from the front, 60 minutes of light only, and 60 minutes of dark by spraying water from the back.[21] It has been reported that 300 hours of UV aging with reference parameters corresponds to approximately 1 year of clinical use.[16] In this study, the total energy delivered and dark–light cycle times were calculated via a UV aging tester, and the UV aging procedures were applied to reflect approximately 1 month of clinical use.

The data were analyzed via SPSS V23.0 software. The Shapiro–Wilk test was used to determine whether the data were normally distributed. Nonparametric data were statistically analyzed with the Kruskal–Wallis H test, and pairwise comparisons were performed with the post hoc Dunn test (P<0.05).

RESULTS

The mean, standard deviation, median, minimum and maximum values of color change and the translucency parameter for each group according to the finishing and polishing steps are presented in Table 3.

Table 3: Color change and translucency parameters for each group according to the finishing and polishing procedures (mean, standard deviation, median, minimum and maximum values)

	Color change (ΔE_{00})		**Translucency parameter (TP_{00})**	
Test groups	Mean ± SD	Median (Min–Max)	Mean ± SD	Ortanca (Min–Max)
1	0.87 ± 0.36	0.86 (0.47 – 1.5) ab	17.02 ± 0.63	17.02 (16.35 – 18.21) ac
2	0.85 ± 0.69	0.71 (0.11 – 1.94) b	16.7 ± 0.42	16.59 (16.21 – 17.21) ac
3	1.01 ± 0.42	0.8 (0.51 – 1.5) ab	19.05 ± 0.28	19.12 (18.55 – 19.35) bc
4	0.59 ± 0.39	0.53 (0.29 – 1.43) b	18.33 ± 0.2	18.23 (18.12 – 18.65) bc
5	0.58 ± 0.29	0.63 (0.2 – 1.03) b	20.02 ± 0.29	20.12 (19.38 – 20.21) b

6	2.66 ± 0.48	2.44 (2.19 – 3.5) [a]	13.68 ± 0.38	13.68 (13.21 – 14.12) [a]
p*	**0.001**		**<0.001**	

Different lowercase letters in the same column indicate statistically significant differences between groups (*P*<0.001).

The different finishing and polishing procedures were statistically significant in terms of color change and translucency (*P*<0.001). The only crystallized samples (group 6) exhibited the highest color change (*P*<0.001). The samples that were only crystallized presented more color changes than those that were crystallized+polished with polishing paste (group 2), crystallized+glazed+polished with polishing paste (group 4), and crystallized with glaze together (group 5) (*P*<0.001). There was no difference between groups 1 and 3, which were just polished with discs or just glazed after crystallization (*P*>0.001). The lowest translucency values were presented in the samples that just crystallized (group 6). The highest translucency values were presented in the ceramics crystallized with glaze together (group 5), which were significantly different from those in the crystallized (group 6), crystallized+polished with discs (group 1), and crystallized+polished with polishing paste (group 2) ceramics (*P*<0.001).

DISCUSSION

According to the results of this in vitro study, different finishing and polishing procedures affected the color change and translucency parameter of the ceramic samples. Thus, the null hypothesis was rejected.

Polishing or glazing methods are essential for ensuring the smoothness of CAD/CAM ceramic restoration surfaces. The results of this in vitro study demonstrated that polishing and/or glazing after crystallization create better surfaces that resist color changes against UV aging cycles for zirconia-reinforced lithium silicate ceramics. Parallel results were emphasized by Manziuc et al. [6] and Kim et al.[18], who reported that color and translucency changed after glazing for monolithic zirconia restorations.

For zirconia-reinforced lithium silicate ceramic restorations, the manufacturer recommends polishing with polishing sets instead of glazing. While there was no significant difference in terms of color change between the polished and glazed groups, the translucency parameters differed. The highest translucency values were presented in ceramics crystallized with glaze together. Translucency is an important property in matching natural tooth appearance and has been reported as a critical esthetic parameter for dental materials.[22,23] Producing more translucent restorations results in more aesthetic results because of the translucent appearance of natural teeth. Based on these results, glazing can be the preferred finishing method for zirconia-reinforced lithium silicate ceramic restorations when translucency is a key consideration.

Traditionally, thermal treatment processes for all ceramic restorations are separate stages that include crystallization and glaze firing. However, this additional firing for glazing has been emphasized to weaken the mechanical characteristics of the lithium disilicate glass ceramics.[24] Recently, CAD/CAM ceramics have made it possible to combine the glazing step with crystallization firing. There was no significant difference between the tested groups glazed with crystallization and those glazed after crystallization in terms of color change. Reducing the number of firing steps may be an alternative to a two-step procedure and can also save time for both the clinician and the patient.

Color measurements of dental materials can be performed by colorimeters, spectroradiometers or spectrofotometers according to the identified standard: ISO/TR

28642.[25] Colorimeters are widely used and reliable devices for color measurements of dental ceramics, as they are appropriate when providing standardization and numerical expression; therefore, in the present study, they are used for color evaluation.[26] In addition, all the samples were fixed to provide immobilization during color measurements and to minimize the edge-loss effect. The mean color difference (ΔE_{00}) and translucency parameter (TP_{00}) were calculated according to the new color difference formula (CIEDE2000), which has been recommended by the CIE based on the CIELAB color space.[27]

The correlation between the surface roughness and translucency of dental ceramics was investigated, and it was reported that smoother surfaces demonstrated higher reflectances and lower transmittances.[28] Incesu et al.[12] investigated the impact of various polishing kits on the roughness of dental ceramics and emphasized that glazing or polishing with OptraFine polishing kits (Ivoclar Vivadent AG, Schaan, Liechtenstein) showed similar results for monolithic zirconia. In this study, no difference was observed in terms of color change between glazing and polishing with discs. Considering the results of both studies, it is supported that surface roughness and optical properties may be related. In parallel with the findings of this study, Ozen et al. [29] reported that manual polishing and glazing had similar effects on the color change of zirconia-reinforced lithium silicate ceramics and defined manual polishing as an alternative to glaze firing. Additionally, many researchers have achieved smooth surfaces or acceptable color change values with manual polishing techniques.[16,30,31] Fasbinder and Neiva [30] obtained smoother surfaces compared to glazed ceramic surfaces when different polishing techniques were applied. Lawson and Burgess [31] polished different CAD/CAM restorative materials and observed clinically acceptable color changes when they were subjected to 1 year of artificial staining. Kılınç and Turgut [16] recommended manual polishing or glazing as a suitable finishing method for the color stability of CAD/CAM ceramic materials. However, in this study, the lowest color change was observed in the groups applied diamond polishing paste after glazing. The resistance of this group to color change may be explained by the chemical contents of the paste that make the surface smoother.

The highest color change and lowest translucency values were observed in the groups that were not glazed or polished after crystallization firing. According to these results, it can be concluded that additional procedures, such as glazing or polishing, are needed to obtain a more aesthetic appearance after crystallization of the blocks milled by CAD/CAM systems. Similar conclusions were drawn by Kurt et al. [1], Manzuic et al. [6], and Kim et al. [18]. It has been reported that optical properties of monolithic zirconia change after glazing, and finishing procedures affect the surface characteristics of monolithic zirconia ceramics.[1,6,18]

The improvement in the translucency of monolithic zirconia has made this material a more aesthetic option in clinical treatment plans. However, care should be taken when firing temperatures, and zirconia restorations should not be subjected to water before sintering, as the opacity of the materials can be affected, resulting in unaesthetic appearance of the final restoration.[32]

The limitations of this study include that only optical parameters were tested and that the surface properties were not evaluated, as it is known that surface texture is related to optical parameters. Additionally, the preparation of rectangular shaped samples, instead of manufacturing them as CAD/CAM restorations, may be considered a limitation. Future studies should investigate the strength and surface properties of these ceramics in clinically relevant designs to better reflect in vivo conditions.

CONCLUSIONS

When the results obtained within the limits of the study are evaluated:

1) Glazing or mechanical polishing of zirconia-reinforced lithium silicate ceramics produces similar results in terms of optical properties.

2) Crystallization with glazing together can be a preferable finishing method for monolithic zirconia-reinforced lithium silicate ceramics as a color-resistant and time-saving option.

3) Finishing monolithic CAD/CAM restorations with glazing or polishing is necessary after crystallization, as it can influence the final optical appearance.

Ethical Approval

Since sources obtained from humans or animals were not used in this study, ethics committee approval was not obtained.

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Conflict of Interest

The authors deny any conflicts of interest related to this study.

Author Contributions

Design: SÜA, Data collection and processing: SÜA, EAA, Analysis and interpretation: EAA, Literature review: SÜA, Writing: SÜA, EAA.

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