

Effect of chemical or mechanical finishing/polishing and immersion in staining solutions on the roughness, microhardness, and color stability of CAD-CAM monolithic ceramics

Mauro GA Brito , Flávia LB Amaral , Cecília P Turssi , Roberta TB Hofling ,
Fabiana MG França 

Instituto e Centro de Pesquisas Odontológicas São Leopoldo Mandic, Dental Materials department, Campinas, Brazil.

ABSTRACT

During the manufacture of ceramic restorations there is an important step of finishing and polishing and the effects of different types of these procedures on the surface characteristics of ceramics are not known for sure. **Aim:** To evaluate the effects of various surface treatments and immersion in coloring substances on the roughness, microhardness, and color stability of CAD-CAM monolithic ceramics. **Materials and Method:** The ceramics used were lithium disilicate reinforced with zirconium dioxide (Suprinity), lithium disilicate (E.max) or leucite (Empress). They were subjected to two surface treatments: glazing (group G) (n=20) or mechanical polishing (group P) (n=20). Then they were divided into two subgroups (n=10) to be treated with the staining substance (coffee or water). Roughness, microhardness and color were measured before and after treatment. Data were subjected to analysis of variance and multiple comparisons were performed with Tukey tests at 5% significance level. **Results:** Roughness was lower in all tested ceramics after polishing than after glazing. Microhardness was the same for polished and glazed E.max, higher in glazed than polished Empress, and higher in polished than glazed Suprinity. Analysis of the effects of glazing and polishing on the individual ceramics showed that the ΔE_{2000} and ΔWID data of the E.max ceramic subjected to polishing showed greater change. Mechanical polishing is a good option for surface treatment of monolithic ceramics. **Conclusion:** Glazing was inferior and less satisfactory than polishing. Glazing generates changes that can lead to color instability.

Keywords: ceramics - dental polishing - materials testing.

Efeito do acabamento/polimento químico ou mecânico e imersão em soluções manchantes na rugosidade, microdureza e estabilidade da cor em cerâmicas monolíticas CAD-CAM

To cite:

Brito MGA, Amaral FLB, Turssi CP, Hofling RTB, França FMG. Effect of chemical or mechanical finishing/polishing and immersion in staining solutions on the roughness, microhardness, and color stability of CAD-CAM monolithic ceramics. Acta Odontol Latinoam. 2023 Aug 30;36(2):86-95. <https://doi.org/10.54589/aol.36/2/86>

Corresponding Author:

Fabiana Mantovani Gomes França
biagomes@yahoo.com

Received: March 2023.

Accepted: June 2023.



This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License

RESUMO

Durante a confecção de restaurações cerâmicas existe uma importante etapa dos procedimentos de acabamento e polimento. Os efeitos de diferentes tipos desses procedimentos nas características superficiais das cerâmicas não são conhecidos com certeza. **Objetivo:** Avaliar os efeitos de vários tratamentos de superfície e imersão em substâncias corantes na rugosidade, microdureza e estabilidade de cor de cerâmicas monolíticas CAD-CAM. **Materiais e Métodos:** As cerâmicas utilizadas foram dissilicato de lítio reforçado com dióxido de zircônio (Suprinity), dissilicato de lítio (E.max) ou leucita (Empress). Foram submetidos a dois tratamentos de superfície: glazamento (grupo G) (n=20) ou polimento mecânico (grupo P) (n=20). Em seguida, foram divididos em dois subgrupos (n=10) para serem tratados com a substância corante (café ou água). Rugosidade, microdureza e cor foram medidas antes e após o tratamento. Os dados foram submetidos à análise de variância e as comparações múltiplas foram realizadas com testes de Tukey ao nível de 5% de significância. **Resultados:** A rugosidade foi menor em todas as cerâmicas testadas após o polimento do que após o glazamento. A microdureza foi a mesma para o E.max polido e vidrado, maior no Empress vidrado do que no polido, e maior no Suprinity polido do que no vidrado. A análise dos efeitos do esmaltação e polimento nas cerâmicas individuais mostrou que os dados ΔE_{2000} e ΔWID da cerâmica E.max submetida ao polimento apresentaram maior alteração. O polimento mecânico é uma boa opção para o tratamento superficial de cerâmicas monolíticas. **Conclusão:** A aplicação do glazing foi inferior e menos satisfatório que o polimento, gerando alterações que podem levar à instabilidade da cor.

Palavras-chave: cerâmica - polimento dentário - ensaios de materiais.

INTRODUCTION

Dental ceramic technology has developed significantly over time in response to clinical needs. Feldspathic ceramic crowns were first introduced by Land, and aluminum oxide (Al₂O₃) was added in 1965 by McLean, with the aim of improving ceramic mechanical-physical properties. Since then, the literature records the introduction of numerous metal-free materials and systems¹.

As techniques for the fabrication of all-ceramic restorations advanced, monolithic restorations were created, i.e., parts made entirely from a single type of ceramic and at the same time. This technique eliminates the need for an overlay or top layer, thereby shortening fabrication time, eliminating problems associated with bonding between layers, and allowing more conservative tooth wear for prosthetic purposes².

Monolithic dental restorations using CAD-CAM technology have become popular due to their excellent mechanical properties and favorable esthetics, without the need for a veneering ceramic. Monolithic restorations can be shaped into final form using CAD-CAM equipment and materials such as zirconia, lithium disilicate ceramics, zirconia-reinforced lithium disilicate, feldspathic ceramics, leucite-based ceramics, and glass/ceramic polymer materials³.

The complexity of tooth color does not appear to be achievable with any existing restorative material. Light reaching the surface of the tooth is partially absorbed, making it difficult for hard tooth structures to scatter, transmit or reflect it. Recent research has shown that these physical effects occur as optical phenomena on the surface and within tooth structures, and are strongly influenced by tooth type⁴.

Although color change has been extensively studied in dentistry, there is still no consensus in the literature on acceptable and unacceptable values of ΔE change. The most usual classification states that ΔE values below 1 are considered clinically imperceptible and are not perceived by the human eye. Values between 1 and 3.3 are considered clinically acceptable and are perceived only by trained operators, while values above 3.3 are considered clinically unacceptable because they can be perceived by untrained observers⁵.

Ceramic systems offer different opacities and a wide range of colors to suit any clinical situation and

act as “biomimetic,” with optical and mechanical properties similar to those of the tissue being replaced. However, these materials must be handled with care, as significant color differences have been observed between the same shades from different lot numbers and between brands with similar color designations, which may affect the esthetic outcome of the final restoration⁶.

When a ceramic restoration is placed, the occlusal adjustment of a crown may roughen the surface, so the restoration must be polished and finished. Many different polishing systems are recommended for ceramic restorations, though it is unclear whether they can all achieve a smooth surface that is the same as or better than the original or untreated surface⁷.

The aim of this study was to investigate the effects of chemical and mechanical finishing/polishing (glaze and manual mechanical polishing) and immersion in a coloring substance on the roughness, color stability, and microhardness of CAD-CAM lithium silicate monolithic ceramics: zirconia-reinforced, lithium disilicate-reinforced, and leucite-reinforced. The null hypothesis tested was that there was no effect of the type of ceramic, finishing/polishing type, or immersion substances on the roughness, microhardness or color stability of the materials.

MATERIALS AND METHOD

Experimental setup

Experimental units: 120 rectangular plates of ceramic CAD-CAM material (14 mm x 12 mm x 2 mm).

Factors studied:

- 3-stage ceramic CAD-CAM: (1) lithium disilicate reinforced with zirconium dioxide (SiO₂-Li₂O-ZrO₂) (VITA Suprinity® - Vita Zahnfabrik®), (2) lithium disilicate (Li₂Si₂O₅) (IPS E.max® CAD - Ivoclar Vivadent®) and (3) reinforced with leucite (SiO₂-Al₂O₃-K₂O) (IPS Empress® CAD - Ivoclar Vivadent®).
- Staining substances in two stages: Coffee and distilled water.
- Two surface treatments: (1) Glaze (IPS Ivocolor Glaze Paste - Ivoclar Vivadent® / Akzent Plus Glaze Paste - Vita Zahnfabrik®) and (2) mechanical polishing with sandpaper in three grit levels: 600, 800 and 1200.
- Reaction variables - evaluation of surface roughness, color and microhardness (before

and after immersion in the staining substance). Figure 1 illustrates the experimental design.

were then cleaned ultrasonically in distilled water for 10 minutes and air dried.

Test specimen preparation

To obtain the ceramic specimens, a high concentration diamond disk (BUEHLER® - IsoMetMT Diamond Wafering Blades 102 x 0.3 mm 15HC) was used in a metallographic cutter (BUEHLER®) to cut the ceramic blocks at a thickness of 2 mm, obtaining rectangular slices with dimensions 14 mm x 12 mm x 2 mm. The slices were placed in the ceramic oven to crystallize, according to the recommendations of the respective manufacturers.

Finishing/Polishing Process

The specimens were subjected to two types of finishing/polishing: In groups G1, G2 and G3 (n=20), a thin layer of glaze was applied according to the recommendations of the manufacturer of the respective ceramic brand. In groups P1, P2 and P3 (n=20), the specimens were mechanically polished in a polishing machine (Aropol 2V - Arotec Ind. e Comércio) with sandpaper (Wetordry™ Sandpaper - 3M ESPE®) at three grit levels (600, 800 and 1200) under running water for 60 seconds. They

Immersion in staining solutions

The specimens were again divided into two subgroups (n=10) according to the staining substance. Each subgroup was immersed in 200 mL of either a solution of Melitta soluble coffee or distilled water (control), both refreshed daily. During immersion, the containers were sealed with PVC film to prevent evaporation. Immersion time was 3 hours daily at room temperature for a test period of 30 days.

At the end of each immersion period, specimens were washed with distilled water, dried, and stored in plastic bottles with cotton soaked in distilled water and placed in a bacteriological oven at 37°C. Two weeks after the end of immersion, the specimens were tested for surface roughness, color, and microhardness.

Surface roughness

Specimen surface roughness (Ra) was determined after surface treatment and again after immersion in coloring substances, using a roughness meter (SJ-210, Mitutoyo, Kanagawa, Japan). Roughness

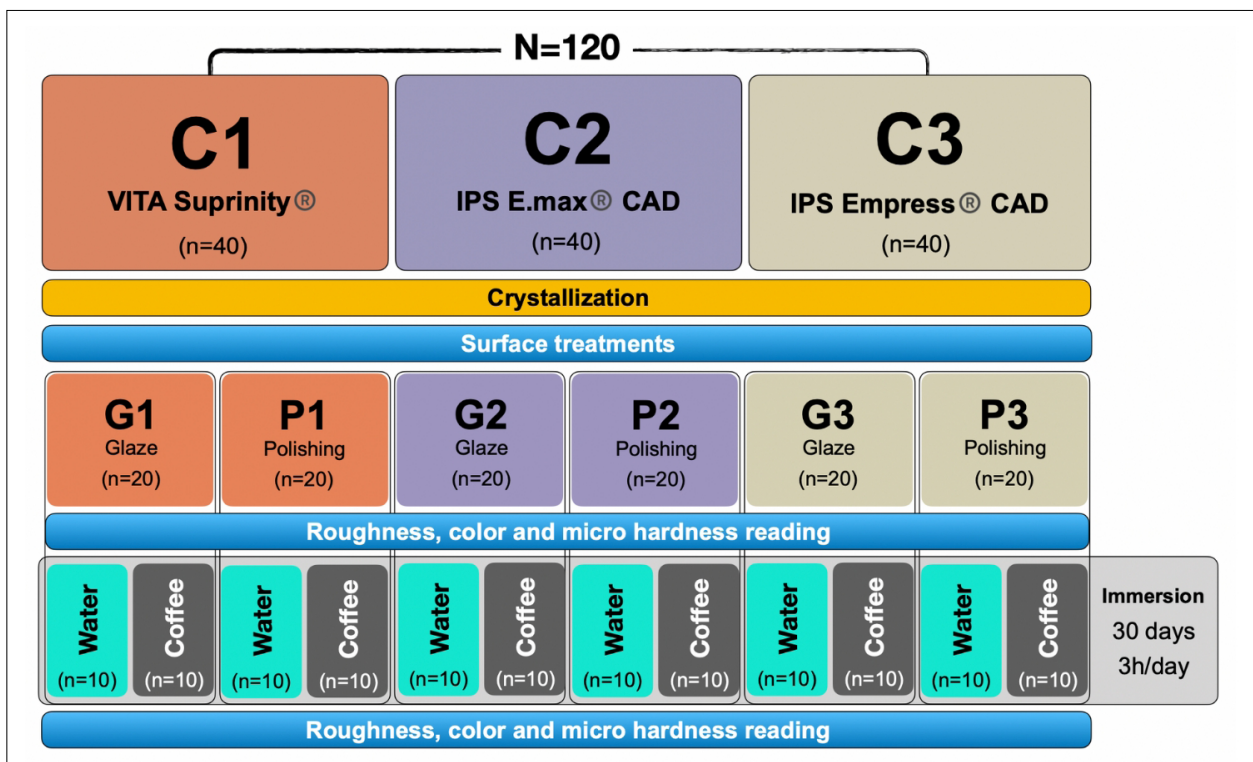


Fig. 1: Diagram showing experimental design.

values were obtained by averaging 3 measurements with a cutoff value of 0.25 mm.

Microhardness

Surface microhardness was tested before and after immersion in water and coffee using a microhardness tester (Pantec HVS, Panambra, São Paulo, SP, Brazil) and a Knoop indenter with a load of 50 grams and an application time of 5 seconds. Three impressions were made on the top of each specimen.

Color stability

Specimen color was recorded twice: after surface treatment and after immersion in the staining solutions, using a digital spectrophotometer (VITA Easyshade® - VITA Zahnfabrik), following the manufacturer's instructions. Color was evaluated based on the difference of the CIELab parameters (ΔL , Δa , Δb), ΔE_{00} and ΔWID ; according to the following formulas: $\Delta E_{00} = \sqrt{(\Delta L^*/k_{LSL})^2 + (\Delta C^*/k_{CSC})^2 + (\Delta H^*/k_{HSH})^2} + RT$ ($\Delta C^*/k_{CSC}$) ($\Delta H^*/k_{HSH}$).

In the ΔE_{00} formula, ΔL^* represents the variation in the L^* coordinate, which indicates brightness (black-white axis); ΔC represents differences in saturation (chroma); ΔH represents differences in hue; and RT is a function that accounts for the interaction between chroma and hue differences in the blue region of the spectrum. The values of ΔE_{00} are calculated sequentially following Sharma et al.⁸. In addition to the above formulas, the variation between the time points and the initial values of the CIEL*a*b* coordinates are calculated by the whiteness index in dentistry (ΔWID) considering the linear formula (WID) at each time point studied: $WID = 0.511L^* - 2.324a^* - 1.100b^*$.

Statistical analysis

The SPSS 23 program (SPSS Inc., Chicago, IL, USA) was used for the statistical calculations, and the significance level was set at 5%. The data for roughness, microhardness, and color parameters L , a , and b , obtained in the first phase of the experiment, when the ceramics had been subjected to surface treatment, were subjected to two-way ANOVA. These were also used after the glazed or polished ceramics had been immersed in distilled water or coffee. The mean differences between the values measured in the second and first stages were

presented descriptively. The ΔE_{2000} - and ΔWID -data were subjected to a three-way repeated measure ANOVA. Multiple comparisons were performed using Tukey tests.

RESULTS

The results were ordered according to the analyses performed: 1) in the first phase of the experiment, when the ceramics were subjected to surface treatment; 2) in the second phase of the study, after the glazed or polished ceramics were immersed in distilled water or in coffee; 3) for ΔE_{2000} and ΔWID .

First stage: ceramics subjected to surface treatment

The two-way analysis of variance applied to the first stage of the experiment showed statistically significant interaction between the ceramics and the surface treatments in terms of roughness, microhardness, and color parameters 'a' and 'b' ($p < 0.001$). For the color L parameter, there was no interaction between ceramics and surface treatments ($p = 0.318$), but a significant difference was observed between ceramics and between surface treatments ($p < 0.001$).

Roughness

For each of the ceramics tested, smoothness was significantly higher when polished than when glazed. During polishing, Suprinity and Empress ceramics, which did not differ from each other, were significantly less rough than E.max. After glazing, Empress ceramics had an average roughness significantly different from Suprinity and E.max, which were the least and most rough, respectively (Table 1).

Microhardness

For E.max ceramic, microhardness did not differ significantly between glazed and polished surfaces. For Empress ceramic, microhardness was significantly higher for glazed surface, while for Suprinity ceramic, it was significantly higher for polished surface (Table 1).

Color 'L' parameters

Significantly higher values were found when polished, regardless of the ceramic used. Regardless of whether the specimens were glazed or polished,

Table 1. Means and standard deviations of roughness, microhardness and color parameters L, a and b, according to the ceramic and its surface treatment and these groups after immersion in coffee and distilled water.

<i>First stage of the experiment: ceramics subjected to surface treatments (glazing or polishing)</i>											
Ceramic	Roughness (μm)		Microhardness (kg/mm^2)		Color 'L' parameter			Color 'a' parameter		Color 'b' parameter	
	Glazing	Polishing	Glazing	Polishing	Glazing	Polishing	Average	Glazing	Polishing	Glazing	Polishing
<i>E.max CAD</i>	0,603 Cb (0,170)	0,144 Ba (0,145)	511 Ba (79)	505 Ba (84)	87,9 (1,2)	90,0 (1,6)	89,0 B (1,7)	1,2 Aa (0,4)	1,0 Ba (0,1)	23,6 Aa (1,6)	24,5 Ba (0,8)
<i>Empress CAD</i>	0,462 Bb (0,129)	0,075 Aa (0,028)	462 Ab (60)	372 Aa (58)	88,6 (1,0)	91,5 (0,9)	90,0 B (1,7)	1,1 Ab (0,3)	0,4 Aa (0,1)	23,3 Ab (1,5)	21,6 Aa (0,9)
<i>Suprinity</i>	0,148 Ab (0,083)	0,054 Aa (0,046)	547 Ca (45)	616 Cb (33)	82,1 (7,6)	86,4 (1,5)	84,2 A (5,8)	8,9 Bb (4,2)	0,2 Aa (0,4)	47,7 Bb (14,3)	23,6 ABa (2,4)
<i>Overall average</i>	—	—	—	—	86,2 a (5,3)	89,3 b (2,5)	—	—	—	—	—
<i>Second stage of the experiment: groups formed by ceramics with treated surface and submitted to immersion in distilled water or coffee</i>											
Ceramic and treatment	Roughness (μm)		Microhardness (kg/mm^2)		Color 'L' parameter		Color 'a' parameter		Color 'b' parameter		
	Water	Coffee	Water	Coffee	Water	Coffee	Water	Coffee	Water	Coffee	
<i>E.max CAD glazing</i>	0,563 Da (0,130)	0,715 Db (0,250)	483 Ca (66)	538 Db (52)	87,3 Aa (1,4)	88,4 ABa (1,0)	1,1 Ba (0,4)	1,1 Ba (0,4)	23,5 Aa (1,9)	23,8 ABa (1,9)	
<i>E.max CAD polishing</i>	0,174 Ba (0,200)	0,148 Ba (0,132)	476 Ca (51)	529 Db (37)	90,1 Ba (1,9)	89,2 Ba (0,7)	1,2 Ba (0,1)	1,1 Ba (0,2)	24,9 Aa (0,9)	27,4 Ba (9,8)	
<i>Empress CAD glazing</i>	0,409 Ca (0,125)	0,603 Cb (0,108)	440 Ba (80)	505 Cb (63)	88,5 Aa (0,8)	88,1 ABa (1,3)	1,2 Ba (1,0)	1,1 Ba (0,4)	22,2 Aa (1,4)	23,6 ABa (1,8)	
<i>Empress CAD polishing</i>	0,078 Aa (0,071)	0,074 Aa (0,048)	377 Aa (29)	411 Ab (86)	92,0 Ba (1,0)	91,1 Ba (0,8)	0,5 Aa (0,1)	0,5 Aa (0,1)	22,0 Aa (0,6)	21,7 Aa (0,3)	
<i>Suprinity glaze</i>	0,181 Ba (0,074)	0,176 Ba (0,101)	512 Da (49)	494 Ca (75)	96,0 Cb (9,3)	86,2 Aa (9,9)	2,4 Ca (4,0)	7,6 Cb (4,9)	24,0 Aa (12,6)	42,6 Cb (16,5)	
<i>Suprinity polida</i>	0,052 Aa (0,039)	0,048 Aa (0,026)	575 Eb (20)	447 Ba (25)	86,0 Aa (0,8)	86,4 Aa (2,0)	0,2 Aa (0,3)	0,5 Aa (0,5)	24,5 Aa (1,2)	23,8 ABa (3,3)	

Considering each response variable separately, capital letters indicate comparisons within each column (ceramics among themselves), while lowercase letters indicate comparisons within each row (glaze x polishing or distilled water x coffee). Means followed by distinct letters differ significantly from each other. Overall averages for parameter L, whose interaction effect was not significant, show comparisons between ceramics (capital letters) and between surface treatments (lower letters).

the highest L values were found for the E.max and Empress ceramics, with no significant difference between the two (Table 1).

Color 'a' parameters

No difference was found between specimens of E.max ceramics that were glazed or polished, while in the other ceramics, the values of 'a' were significantly higher when glaze was applied. No statistically significant difference was found between glazed E.max and Empress, but they both had significantly lower 'a' values than Suprinity. After polishing, the 'a' parameter was significantly higher

in E.max ceramics, with no significant difference between the other two ceramics (Table 1).

Color 'b' parameters

The results are identical to those found for the 'a' parameter. The only difference was that the Suprinity ceramic did not differ significantly from Empress when polished (Table 1).

Second stage: after immersing the glazed or polished ceramics in distilled water or coffee

Two-way analysis of variance showed that there was a statistically significant interaction for roughness

data ($p = 0.017$), microhardness, and parameters L, a, and b ($p < 0,001$). There was a statistically significant interaction between the surface-treated ceramics and the immersion factor in staining solution.

Roughness

After immersion in coffee or distilled water, there was no significant change in surface roughness of the polished specimens or the glazed Suprinity specimens. However, surface roughness of the glazed E.max and Empress specimens increased in coffee.

After immersion in water, glazed E.max had significantly higher surface roughness than Empress specimens, which in turn were rougher than polished E.max and glazed Suprinity. Polished E.max and glazed Suprinity did not differ from each other, but were rougher than polished Empress and Suprinity, which had the lowest roughness values.

After immersion in coffee, the results for the glazed or polished ceramics were identical to those described for immersion in distilled water (Table 1).

Microhardness

Except for the glazed and polished Suprinity ceramics, which showed no significant difference when immersed in coffee or water and showed significantly lower microhardness when immersed in coffee, microhardness was significantly lower for all other combinations of ceramics and surface treatment after immersion in distilled water.

After immersion in water, polished Suprinity had significantly higher microhardness than glazed Suprinity. It was followed by E.max (both polished and glazed, which did not differ significantly from each other). E.max in turn had significantly higher microhardness than the glazed Empress, while polished Empress had the lowest values under all conditions.

After immersion in coffee, polished and glazed E.max, which did not differ significantly from each other, had higher microhardness than glazed Empress and Suprinity, which also did not differ from each other. Polished Suprinity and Empress had the lowest microhardness values (Table 1).

L Parameters

The values of parameter L of the specimens immersed in water or coffee did not differ

significantly for any combination of ceramics and surface treatment, except for glazed Suprinity, which showed a significantly lower L value after immersion in coffee.

After immersion in water, glazed Suprinity ceramic had a significantly higher L-value than the polished E.max and Empress ceramics (with no significant difference between the two), and these had higher values than glazed E.max, glazed Empress and polished Suprinity.

After immersion in coffee, polished and glazed Empress and E.max, which did not differ from each other, had significantly higher L values than both glazed and polished Suprinity, while glazed E.max and Empress had medium values of the color L parameter (Table 1).

Color 'a' parameters

The only ceramic whose 'a' color parameter was significantly affected by coffee was glazed Suprinity. After both water immersion and coffee immersion, this was the group that had the highest 'a' value, followed by E.max (both glazed and polished) and glazed Empress (with no significant difference between these three groups). The lowest value of a was measured in the polished Suprinity group (Table 1).

Color 'b' parameters

Coffee only increased the value of parameter 'b' significantly in glazed Suprinity.

After immersion in distilled water, there was no significant difference among the various ceramic and surface treatment combinations.

After immersion in coffee, the highest 'b' value was found for glazed Suprinity, followed by polished E.max, which was in turn higher than polished Empress. After immersion in coffee, glazed E.max, glazed Empress and polished Suprinity did not differ significantly from each other or from any of the other groups (Table 1).

ΔE_{2000} and ΔWID

The three-way repeated measure ANOVA found no significant interaction among the factors studied (ceramic, surface treatment, and staining solution) for either the ΔE_{2000} ($p = 0.268$) or the ΔWID ($p = 0.495$) data. The dual interactions between ceramics and surface treatment (ΔE_{2000} : $p = 0.127$; ΔWID : $p = 0.633$) and between surface treatment and staining

Table 2. Means and standard deviations of the ΔE_{2000} and ΔWID parameters, according to the ceramic, its surface treatment and immersion in water and coffee.

Response variable	Ceramic	Glaze		Polishing	
		Water	Coffee	Water	Coffee
ΔE_{2000}	E.max CAD	0,40 (0,17)	0,33 (0,23)	0,31 (0,21)	1,47 (3,4)
	Empress CAD	0,64 (0,81)	0,62 (0,20)	0,33 (0,20)	0,60 (0,26)
	Suprinity	11,89 (7,18)	7,13 (8,38)	0,45 (0,27)	0,61 (0,35)
ΔWID	E.max CAD	-0,77 (0,78)	0,81 (0,89)	-0,68 (0,73)	-3,75 (10,72)
	Empress CAD	-0,04 (2,56)	0,46 (0,99)	0,22 (0,80)	-1,31 (1,04)
	Suprinity	34,87 (34,49)	23,83 (35,40)	-0,42 (1,06)	-1,49 (1,47)

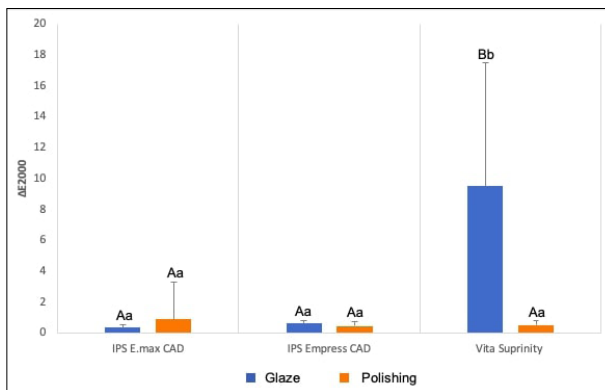


Fig. 2: Column diagram of the average values of ΔE_{2000} , according to the ceramic and its surface treatment, regardless of immersion in water and coffee.

Caption: Blue columns indicated with distinct capital letters indicate a significant difference between ceramics that received glaze. Red columns indicated with equal capital letters indicate no significant difference between polished ceramics. Columns with equal lowercase letters indicate no significant difference between glazed and polished samples, considering each ceramic separately.

solution (ΔE_{2000} : $p = 0.083$; ΔWID : $p = 0.838$) were not significant. The interaction between ceramic and surface treatment was statistically significant for the ΔE_{2000} and ΔWID data ($p < 0.001$) (Table 2).

Breaking down the interaction between ceramics and surface treatment for the ΔE_{2000} data, no difference was found between glazed and polished E.max or Empress, but for Suprinity, delta values were significantly higher for glazed. While the polished ceramics did not differ significantly from each other, glazed ceramics differed significantly, with Suprinity having significantly higher values than the other materials, between which no significant difference was found (Fig. 2).

For the ΔWID data, the comparisons between the ceramics gave the same results as for ΔE_{2000} . Analysis of the effects of glazing and polishing

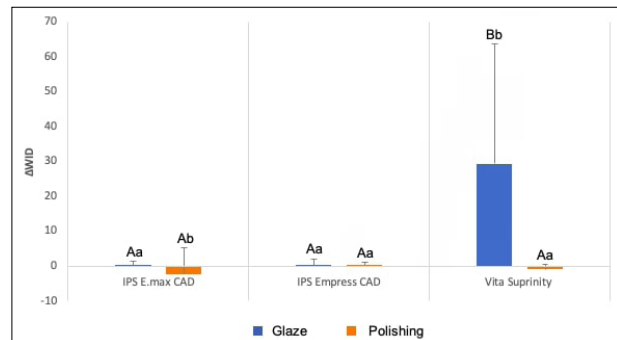


Fig. 3: Column diagram of the average values of ΔWID , according to the ceramic and its surface treatment, regardless of immersion in water and coffee.

Caption: Blue columns indicated with distinct capital letters indicate a significant difference between ceramics that received glaze. Red columns indicated with equal capital letters indicate no significant difference between polished ceramics. Columns with distinct lowercase letters indicate a significant difference between glazed and polished samples, considering each ceramic separately.

on the individual ceramics showed that the only difference from the ΔE_{2000} data was that polished E.max resulted in greater changes (Fig. 3).

Immersion in water or coffee had no effect on ΔE_{2000} values [$p = 0.378$; water immersion: 2.33 (5.15); coffee: 1.79 (4.29)], or on ΔWID [$p = 0.363$; water immersion: 5.53 (18.92); coffee: 3.09 (17.29)], regardless of the ceramic and surface treatment.

DISCUSSION

Surface roughness plays a critical role in preventing extrinsic discoloration⁹. The roughness data from this study showed that smoothness was significantly greater for polished than for glazed ceramics in all three cases (before and after immersion in solutions), although in another study, polishing was found to produce rough surfaces while glazing produced a

smoother surface¹⁰. The difference may be attributed to different specimen preparation techniques, polishing techniques¹¹, materials¹² or Ra machine used¹³. The surface roughness of polished specimens did not differ after immersion in coffee or water. Sandpaper with different grits was used for polishing in this study. A final mirror polish after milling or setting is essential to ensure smooth surfaces ($< 0,2 \mu\text{m}$) with optimal clinical performance. The E.max specimen surface roughness was below this value after each polishing application¹⁴. Polishing in the office is as effective as polishing in the laboratory¹¹.

After immersion in distilled water, microhardness was lower for all polishing and ceramic combinations. Suprinity showed lower microhardness with coffee and glaze. Empress microhardness was higher with glaze. E.max showed no difference between glaze and polish. Suprinity consists mainly of ZrO₂ (zirconia) 8-12 wt%, SiO₂ (silica) 56-64 wt%, Li₂O (lithium oxide) 15-21 wt%, and La₂O₃ (lanthanum oxide) 0.1 wt%. According to the manufacturer, the composition of E.max consists mainly of SiO₂, Li₂O, P₂O₅, ZrO₂, ZnO, K₂O and Al₂O₃, as well as additional dye ions, which are combined using glass technology through a pressure casting process (Vivadent Ivoclar). The partially crystallized blocks used for milling in E.max consist of 40% lithium metasilicate crystals (Li₂SiO₃), with sizes of 0.2 and 1.0 mm and platelet format, fixed in the glass phase together with disilicate cores of lithium (Vivadent Ivoclar). Therefore, the differences in ceramic materials can be attributed to the type and size of the crystalline phase (lithium silicate vs. lithium disilicate) or additional ZrO₂ particles.

Polishing increased the L-value regardless of the material because color stability is affected by the surface structure of the material. The higher L-value could be related to surface irregularities¹². The discoloration caused by coffee can be attributed to the penetration of the yellow coffee dye into the microstructure of the materials. E.max and Empress achieved the highest L values, regardless of whether they were polished or glazed.

Distilled water and coffee affected the surface hardness of the materials studied, which may have increased their susceptibility to staining¹⁵. Fahmy et al.¹⁶ reported a significant increase in the hardness values of a ceramic material after storage in saliva for 3 weeks. This increase in microhardness was related to ion exchange through the Si-OH layer

reportedly formed on the ceramic surface¹⁶.

After immersion in water or coffee, the ceramics, whether polished or glazed, showed no difference in the value of L. Glazed Suprinity had the lowest value of 'a' and L after immersion in coffee and the highest value of L after immersion in water. Immersion in coffee also increased the values of 'a' and 'b' for glazed Suprinity. Due to their low polarity, coffee dyes tend to soak into the ceramic¹⁷. Increases in 'a' and 'b' and a decrease in 'L' always occurred in the presence of glaze. The type of soaking solution can affect the extent of color change. In the present study, a coffee solution was used as the colorant. Odioso et al.¹⁸ reported that coffee/tea consumption was one of the factors that significantly affected 'b' and 'L' values. People who drank coffee or tea daily had an average increase of 1.2 units in 'b' and a decrease of 1.5 units in L. The average time to drink a cup of coffee is 15 minutes, and for coffee drinkers, average coffee intake is 3.2 cups per day¹⁷. Therefore, 48 hours of storage simulated coffee consumption for 2 months¹⁹. It was postulated that 24 hours of immersion *in vitro* is approximately equivalent to one month *in vivo*¹⁹. Therefore, three hours per day of immersion for 30 days is equivalent to 90 days of clinical immersion.

The ΔE_{2000} and ΔWID data confirm that the presence of glaze on all ceramics resulted in higher delta values. Glazed Suprinity exhibited the highest values. Kilinc & Turgut²⁰ reported that manual polishing techniques can achieve similar results to glazing in terms of color stability, which contrasts with Yilmaz et al.²¹, who found that glazed preparations had better color stability, although the observed color was not clinically noticeable in the polished preparations. Suprinity and E.max ceramics treated with different surface treatment procedures (glazing or polishing) showed significant and clinically acceptable differences in color changes after coffee thermal cycling²². Kilinc and Turgut²⁰ also reported clinically acceptable color changes in glass-ceramics, regardless of the type of surface treatment (control, manual polishing, or glazing). They reported that polishing and glazing produced similar results in terms of roughness²³.

Sarac et al.²⁴ investigated the effects of polishing systems on the color and surface texture of ceramics, finding significant differences between polishing techniques in terms of color differences, with ΔE values ranging from 1.03 to 3.36. Glazed specimens

showed better color stability; on the other hand, the discoloration observed in polished specimens was not clinically noticeable¹².

To conclude, mechanical polishing performed better in terms of roughness, surface microhardness, and

color retention of the ceramics studied compared to glazing. Zirconia-based ceramics generally showed more homogeneous results in terms of microhardness and roughness when manual polishing and glazing were considered.

DECLARATION OF CONFLICT OF INTEREST

The authors declare no potential conflicts of interest regarding the research, authorship, and/or publication of this article.

FUNDING

None

REFERENCES

- Silva TM, Salvia AC, Carvalho RF, Pagani C, et al. Polishing for glass ceramics: which protocol? *J Prosthodont Res.* 2014;58:160-170. <https://doi.org/10.1016/j.jpor.2014.02.001>
- Johansson C, Kmet G, Rivera J, Larsson C, et al. Fracture strength of monolithic all-ceramic crowns made of high translucent yttrium oxide-stabilized zirconium dioxide compared to porcelain-veneered crowns and lithium disilicate crowns. *Acta Odontol Scand.* 2014;72:145-153. <https://doi.org/10.3109/00016357.2013.822098>
- Kim HK, Kim SH. Effect of the number of coloring liquid applications on the optical properties of monolithic zirconia. *Dent Mater.* 2014;30:e229-237. <https://doi.org/10.1016/j.dental.2014.04.008>
- PopCiutrilă IS, Ghinea R, Perez Gomez MM, Colosi HA, et al. Dentine scattering, absorption, transmittance and light reflectivity in human incisors, canines and molars. *J Dent.* 2015;43:1116-1124. <https://doi.org/10.1016/j.jdent.2015.06.011>
- Oliveira ALBM, Botta AC, Campos JADB, Garcia PPNS. Effects of Immersion Media and Repolishing on Color Stability and Superficial Morphology of Nanofilled Composite Resin. *Microsc Microanal.* 2014;20:1234-1239. <https://doi.org/10.1017/S1431927614001299>
- Carney MN, Johnston WM. Appearance differences between lots and brands of similar shade designations of dental composite resins. *J Esthet Restor Dent.* 2017;29:E6-14. <https://doi.org/10.1111/jerd.12263>
- Amaya-Pajares SP, Ritter AV, Resendiz CV, Henson BR, et al. Effect of finishing and polishing on the surface roughness of four ceramic materials after occlusal adjustment. *J Esthet Restor Dent.* 2016;28:382-396. <https://doi.org/10.1111/jerd.12222>
- Sharma G, Wu W, Dalal EN. The CIEDE2000 color-difference formula: Implementation notes, supplementary test data, and mathematical observations. *Color Research & Application* 2005;30:21-30. <https://doi.org/10.1002/col.20070>
- Kozmacs C, Hollmann B, Arnold WH, Naumova E, et al. Polishing of Monolithic Zirconia Crowns-Results of Different Dental Practitioner Groups. *Dent J (Basel)* 2017;5:30. <https://doi.org/10.3390/dj5040030>
- Brunot-Gohin C, Duval JL, Azogui EE, Jannetta R, et al. Soft tissue adhesion of polished versus glazed lithium disilicate ceramic for dental applications. *Dent Mater* 2013;29(9):e205-e212. <https://doi.org/10.1016/j.dental.2013.05.004>
- Matzinger M, Hahnel S, Preis V, Rosentritt M, et al. Polishing effects and wear performance of chairside CAD/CAM materials. *Clin Oral Investig* 2019;23:725-737. <https://doi.org/10.1007/s00784-018-2473-3>
- Sarikaya I, Güler AU. Effects of different surface treatments on the color stability of various dental porcelains. *J Dent Sci* 2011;6:65-71. <https://doi.org/10.1016/j.jds.2011.03.001>
- Guilardi LF, Werner A, Jager N, Pereira GKR, et al. The influence of roughness on the resistance to impact of different CAD/CAM dental ceramics. *Braz Dent J* 2021;32: 54-65. <https://doi.org/10.1590/0103-6440202103951>
- Incesu E, Yanikoglu N. Evaluation of the effect of different polishing systems on the surface roughness of dental ceramics. *J Prosthet Dent* 2020;124:100-109. <https://doi.org/10.1016/j.prosdent.2019.07.003>
- Tuncer D, Karaman E, Firat E. Does the temperature of beverages affect the surface roughness, hardness, and color stability of a composite resin? *Eur J Dent* 2013;7:165-171. <https://doi.org/10.4103/1305-7456.110161>
- Fahmy NZ, EL Guindy J, Zamzam M. Effect of Artificial Saliva Storage on Microhardness and Fracture Toughness of a Hydrothermal Glass-Ceramic. *J Prosthodont* 2009;18:324-331. <https://doi.org/10.1111/j.1532-849X.2009.00448.x>
- Ertaş E, Güler AU, Yücel AC, Köprülü H, et al. Color stability of resin composites after immersion in different drinks. *Dent Mater J* 2006;25:371-376. <https://doi.org/10.4012/dmj.25.371>
- Odioso LL, Gibb RD, Gerlach RW. Impact of demographic, behavioral, and dental care utilization parameters on tooth color and personal satisfaction. *Compend Contin Educ Dent Suppl* 2000;S35-41;quiz S43.
- Guler AU, Yilmaz F, Kulunk T, Guler E, et al. Effects of different drinks on stainability of resin composite provisional restorative materials. *J Prosthet Dent* 2005;94:118-124. <https://doi.org/10.1016/j.prosdent.2005.05.004>
- Kilinc H, Turgut S. Optical behaviors of esthetic CAD-CAM restorations after different surface finishing and polishing procedures and UV aging: An in vitro study. *J Prosthet Dent* 2018;120:107-113. <https://doi.org/10.1016/j.prosdent.2017.09.019>
- Yilmaz C, Korkmaz T, Demirköprülü H, Ergün G, et al. Color stability of glazed and polished dental porcelains. *J Prosthodont* 2008;17:20-24.
- Alp G, Subasi MG, Johnston WM, Yilmaz B. Effect of surface treatments and coffee thermocycling on the color and translucency of CAD-CAM monolithic glass-ceramic. *J*

- Prosthet Dent 2018;120:263-268. <https://doi.org/10.1016/j.prosdent.2017.10.024>
23. Vichi A, Fabian Fonzar R, Goracci C, Carrabba M, et al. Effect of Finishing and Polishing on Roughness and Gloss of Lithium Disilicate and Lithium Silicate Zirconia Reinforced Glass Ceramic for CAD/CAM Systems. Oper Dent 2018;43:90-100. <https://doi.org/10.2341/16-381-L>
24. Sarac D, Sarac YS, Yuzbasioglu E, Bal S. The effects of porcelain polishing systems on the color and surface texture of feldspathic porcelain. J Prosthet Dent 2006;96:122-128. <https://doi.org/10.1016/j.prosdent.2006.05.009>