RESEARCH AND EDUCATION

Effect of beverage solutions and toothbrushing on the surface roughness, microhardness, and color stainability of a vitreous CAD-CAM lithium disilicate ceramic

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Dental esthetics has become increasingly important for quality of life and self-esteem.[1,2] The clinical success and longevity of esthetic restorations depend on the type, method of fabrication, surface treatments, conditions of the dental substrate, cementation, marginal adaptation, occlusal adjustments, and the dietary and oral hygiene habits of the patient.[3-6] Balancing and controlling these factors are challenging tasks for clinicians when choosing the best material and technique for each clinical situation.[7,8]

Despite the excellent mechanical properties of present-day ceramics, they are subject to staining, changes in color,

ABSTRACT

Statement of problem. Computer-aided design and computer-aided manufacturing (CAD-CAM) has enhanced the physicomechanical stability of ceramics. However, various factors in the oral cavity may impair the longevity of restorations by negatively affecting their properties. Appropriate surface treatments such as glaze application or mechanical polishing are necessary to diminish these effects.

Purpose. The purpose of this in vitro study was to evaluate the influence of common beverages and toothbrushing on the surface roughness, microhardness, and color stainability of a vitreous CAD-CAM lithium disilicate ceramic with a glazed or mechanically polished surface.

Material and methods. Specimens (N=160) were divided into 2 groups according to the surface treatment method: polishing with abrasive disks or glaze application. Each group was subdivided (n=8) according to the immersion solution and toothbrushing: distilled water and distilled water plus brushing; coffee and coffee plus brushing; black tea and black tea plus brushing; red wine and red wine plus brushing; and cola and cola plus brushing. Before and after simulating a 5-year period of immersion and toothbrushing, a contact profilometer and a Vickers microhardness tester were used to measure the surface roughness and microhardness. CIELab parameters were assessed by using a portable spectrophotometer, and color differences were calculated by using the CIEDE2000 formula (ΔE_{00}). Data were compared by using 3-way ANOVA/Bonferroni test for post hoc analysis (α=.05).

Results. Surface roughness increased irrespective of solution (*P*=.763), being influenced by surface treatment (*P*<.001), with the glazed groups presenting higher values. Microhardness decrease was influenced by solutions (*P*<.038) and surface treatment (*P*<.001), and glazing was associated with lower values. Irrespective of the surface treatment, color stainability was influenced by solutions (*P*<.001), with ΔE_{00} values for red wine being above the perceptibility threshold (ΔE_{00}>1.30). No influence of toothbrushing was found for any parameter (*P*>.05).

Conclusions. Despite its excellent mechanical properties, CAD-CAM lithium disilicate ceramic degraded after exposure to commonly consumed beverages. Irrespective of surface treatment, beverages decreased microhardness and caused color changes. Surface roughness increased, showing higher variation for glazed groups. Toothbrushing was unable to potentiate or diminish the observed effects. In general, the results showed that proper mechanical polishing can produce a surface with desirable properties. (J Prosthet Dent 2019;121:711.e1-e6)

Clinical Implications

Mechanical polishing can protect computer-aided design and computer-aided manufacturing lithium disilicate ceramic restorations against the deleterious effects of common beverages and toothbrushing. Small adjustments can be polished before or after cementation without the need for an additional glazing procedure.

changes in microhardness, and changes in surface roughness from causes of endogenous or exogenous origin.[1,8-13] Colored beverages, acid solutions, elevated temperatures, and toothbrushing are extrinsic factors related to the degradation of ceramics.[1,9,10,13,14] Exogenous staining occurs because of the capacity of the material to absorb or adsorb the pigments of substances present in the oral cavity, varying according to the ceramic composition and surface treatment.[12-15]

Monolithic computer-aided design and computer-aided manufacturing (CAD-CAM) lithium disilicate ceramics have become popular because of their versatility, practicality in fabricating indirect restorations, and the possibility of characterizing with extrinsic staining after milling,[1,7,10] thereby speeding up the restorative treatment. However, they are subject to the process of degradation when exposed to a variety of conditions in the oral cavity.[16-22] These conditions act on the structural composition and interfere in the surface properties of the material. Although crystallization, glazing and reglazing firing cycles, adjustments, and mechanical polishing procedures may be performed on this ceramic, consensus is lacking as to which protocol is most effective in maintaining its properties,[1-3,6,10,12,23,24] especially when the capacity of mechanical polishing kits to create smooth surfaces is compared with that of glazing procedures.[6,21,23,24]

The influence of common beverages, the abrasiveness of toothbrushing, and the association of these factors on the properties of CAD-CAM lithium disilicate with different surface-polishing treatments should be evaluated. Therefore, the purpose of this in vitro study was to evaluate the influence of beverage solutions and toothbrushing on the surface roughness, microhardness, and color stainability of a vitreous CAD-CAM lithium disilicate ceramic with a glazed or mechanically polished surface. The null hypotheses were that the tested solutions would not affect the surface and micromechanical properties tested and that toothbrushing would not be able to alter these effects, irrespective of the type of surface treatment.

MATERIAL AND METHODS

Rectangular-shaped specimens (8×6×1 mm; N=160) were obtained from monolithic lithium disilicate (IPS

e.max CAD HT Blocks; Ivoclar Vivadent AG), shade A2, and divided into 2 groups according to the surface treatment method. Mechanical polishing was performed by using 400-, 600-, and 1200-grit abrasive papers and an electric rotary polishing machine (Aropol 2V; Arotec Ind Com) (polished group; n=80). Manual glazing by using a paste-liquid–type glaze (Glaze Power e.max Ceram; Ivoclar Vivadent AG) was performed by an experienced operator until a homogeneous surface was obtained (glazed group; n=80). All glazed specimens were submitted to 2 crystallization firing cycles in a ceramic furnace (Programat P300; Ivoclar Vivadent AG) at 850 °C, for 20 minutes. Each group was subdivided (n=8) according to the immersion solution and toothbrushing: distilled water and distilled water plus brushing (control groups); coffee (Nescafé; Nestlé Brasil Ltda) and coffee plus brushing; black tea (Leão; Coca-Cola Co) and black tea plus brushing; red wine (Cabernet Sauvignon; Concha y Toro) and red wine plus brushing; and cola (Coca-Cola Co) and cola plus brushing.

According to Guler et al,[25] 24 hours of immersion would simulate approximately 30 days of regular coffee consumption. The same time-simulation protocol was adopted for the other beverages. All specimens were kept in a dark environment at 37 °C for 90 days, simulating 5 years of consumption. Solutions were exchanged after every 24 hours of immersion. Coffee and tea solutions were prepared by dissolving 12 g of coffee powder or 3 g of tea powder in 250 mL of boiled distilled water. Before immersion, the side of each specimen with no surface treatment was covered with duct tape (Scotch, 3M) to avoid contact with the beverages. Before evaluating the properties, the specimens were cleaned in an ultrasonic device (Ultracleaner 1400; Unique Ind Com Prod Eletr Ltda) and dried by using an air spray. Physical properties were assessed before and after immersion.

For the groups subjected to toothbrushing immediately after the 5-year simulation of immersion, the specimens were brushed in a brushing simulation machine (MSET; Elquip). Toothbrushes with soft nylon bristles (Tek; Johnson & Johnson Ind Com Ltda) were used, and 80 000 cycles were performed to simulate 5 years of brushing by applying a brushing movement with a load of 2 N on the specimen surfaces, an amplitude of excursion of 20 mm, and a speed of 4.5 movements per second. A suspension of distilled water and toothpaste (Colgate Total; Colgate-Palmolive Co) was prepared in a ratio of 1:1, and 1 mL of the suspension was then injected onto the specimen surfaces every 30 seconds.[10,26] The internal temperature of the machine was maintained at 37 °C. For these groups, the properties were assessed before immersion and after brushing.

The surface roughness (Ra) was measured by means of a contact profilometer (Hommel Tester T1000; Hommelwerke GmbH) with a vertical resolution of 0.01 µm

Table 1. Three-way ANOVA results for comparison of surface roughness, microhardness, and color stainability

Parameter	Source	F	P^a
Roughness	Solution (S)	0.462	.763
	Toothbrushing (TB)	0.784	.377
	Surface treatment (SP)	666.47	<.001[b]
	S×TB×SP	1.919	<.001[b]
Microhardness	Solution (S)	2.61	.038[b]
	Toothbrushing (TB)	2.18	.141
	Surface treatment (SP)	494.13	<.001[b]
	S×TB×SP	159.90	<.001[b]
Color stainability	Solution (S)	16.08	<.001[b]
	Toothbrushing (TB)	0.124	.519
	Surface treatment(SP)	1.64	.202
	S×TB×SP	11.06	<.001[b]

F, multifactorial. [a]3-way repeated-measures ANOVA. [b]Significant differences (P<.05).

Table 2. Mean results ±standard error and post hoc comparisons for variation in surface roughness, microhardness, and color stainability

Parameter	No Toothbrushing		With Toothbrushing	
	Polishing	Glaze	Polishing	Glaze
Roughness				
WT	-0.01 ±0.01[Aa]	0.02 ±0.01[Aa]	0.03 ±0.02[Aa]	0.06 ±0.08[Aa]
CF	0.00 ±0.00[Aa]	0.06 ±0.02[Aa]	0.00 ±0.01[Aa]	0.06 ±0.02[Aa]
BT	0.01 ±0.01[Aa]	0.12 ±0.03[Bb]	0.02 ±0.02[Aa]	0.06 ±0.03[Aa]
RW	0.02 ±0.02[Aa]	0.00 ±0.03[Aa]	0.00 ±0.02[Aa]	0.04 ±0.06[Aa]
CL	0.01 ±0.01[Aa]	0.01 ±0.02[Aa]	0.01 ±0.01[Aa]	0.04 ±0.02[Aa]
Microhardness				
WT	-75.00 ±13.37[Aa]	-41.38 ±19.74[Aa]	-58.25 ±9.62[Aa]	-57.13 ±17.04[Aa]
CF	-59.88 ±6.97[Aa]	-49.88 ±8.93[Aa]	-54.63 ±10.55[Aa]	-41.13 ±7.61[Aa]
BT	-56.63 ±11.74[Aa]	-39.50 ±9.95[Aa]	-60.75 ±8.00[Aa]	-46.75 ±17.25[Aa]
RW	-53.25 ±14.15[Aa]	-56.50 ±20.99[Aa]	-73.75 ±9.34[Aa]	-54.63 ±10.30[Aa]
CL	-62.63 ±8.00[Aa]	-41.50 ±5.69[Aa]	-67.25 ±8.25[Aa]	-70.13 ±9.32[Aa]
Color stainability				
WT	0.81 ±0.16[Aa]	1.00 ±0.14[Aa]	0.89 ±0.19[Aa]	0.92 ±0.22[Aa]
CF	0.81 ±0.08[Aa]	0.92 ±0.08[Aa]	0.87 ±0.11[Aa]	0.97 ±0.13[Aa]
BT	0.90 ±0.12[Aa]	0.82 ±0.10[Aa]	0.78 ±0.07[Aa]	0.69 ±0.07[Aa]
RW	1.61 ±0.28[Ab]	1.91 ±0.36[Ab]	1.46 ±0.28[Ab]	1.87 ±0.41[Ab]
CL	0.83 ±0.09[Aa]	0.81 ±0.11[Aa]	0.75 ±0.07[Aa]	0.90 ±0.09[Aa]

BT, black tea; CF, coffee; CL, cola; RW, red wine; WT, distilled water. Different uppercase letters (horizontally) and different lowercase letters (vertically) mean significantly different (P<.05).

(accuracy of Ra) and equipped with a diamond tip (5 μm of radius), moving through a 4.8-mm long-rectilinear path for 10 seconds with a constant load of 4 mN and a stylus speed of 0.5 mm/s. The mean value of 3 readings in the central area of each specimen with an incremental distance of 1 mm between each scanning line was defined as the specimen roughness.[2,27]

A hardness tester (FM-ARS 9000; Future-Tech Corp), equipped with a Vickers diamond, was used to assess the surface microhardness. Three indentations placed 500 μm apart were made on the upper margin of each specimen using a 2-N load and a 15-second contact.[9,28] Indentation diagonals were measured, the results generated were reported in Vickers hardness (VHN) units by the machine, and the average of the 3 values was calculated.

A portable digital spectrophotometer (VITA Easyshade; VITA Zahnfabrik) was used to record the color of each specimen.[8,14,18,27] To standardize the assessment location and avoid ambient light, the probe tip was placed 90 degrees perpendicular to the ceramic surface and at the same distance for all readings. The device was aligned by embedding both specimens and probe tip in high-viscosity silicone (Clonage; DFL), and this arrangement was then positioned against a nonreflective white background. Three measurements were obtained in a central area, and the mean value for the parameters L*, a*, and b* was applied in the CIEDE2000 formula (ΔE_{00})[29] to detect color differences resulting from the experimental conditions. The parametric factors of K_L, K_C, and K_H were set to 1; ΔE_{00} values were considered perceptible if above 1.30 and clinically acceptable if below 2.25.[30,31]

Based on a previous study[10] in which a higher color difference was observed for stained and glazed groups together (0.30 ±0.15), when compared with only glazed (0.12 ±0.07) lithium disilicate ceramic subjected to toothbrushing, an estimated sample size of 8 disks per group was deemed necessary to obtain a power of 80%

(α=.05) to represent the hypotheses of the present study (Student t test). The Kolmogorov-Smirnov test was used to check the normality of data. A 3-way repeated-measures ANOVA was performed to identify differences in the effect of beverages, toothbrushing, and the type of surface treatment on the tested material. The Bonferroni test was used for post hoc analysis (α=.05). A statistical software program (SPSS Statistics v17.0; SPSS Inc) was used for the analysis.

RESULTS

The 3-way ANOVA analysis (Table 1) demonstrated that surface treatment influenced the variations in surface roughness (P<.001) and that microhardness (P<.001) and the type of beverage influenced both microhardness (P=.038) and color stainability (P<.001). No influence of toothbrushing was found for any parameter. Furthermore, the interaction among factors was significant for each property (P<.001). The comparison of the effect after immersion for both glazed and polished groups is presented in Table 2.

A significant difference was observed between groups for the initial roughness (glazed groups: 0.38 ±0.01 μm; polished groups: 0.10 ±0.00 μm; P<.001; independent t test). After immersion, the surface roughness increase was not affected by the solution (P=.763), with higher variations occurring in the glazed groups (Table 2). The increase was significant for black tea (P=.004) and coffee (P=.030); black tea caused the

Table 3. Mean results ±standard error for surface roughness (μm) and microhardness (VHN) before and after immersion and brushing

Parameter	No Toothbrushing			With Toothbrushing		
	Baseline	5 Years	P^a	Baseline	5 Years	P^a
Roughness						
Polishing						
WT	0.10 ±0.01	0.09 ±0.00	.677	0.10 ±0.01	0.13 ±0.01	.086
CF	0.10 ±0.02	0.10 ±0.02	.836	0.10 ±0.01	0.09 ±0.01	.850
BT	0.09 ±0.01	0.09 ±0.01	.593	0.12 ±0.01	0.13 ±0.02	.415
RW	0.09 ±0.01	0.11 ±0.01	.311	0.10 ±0.01	0.10 ±0.01	.952
CL	0.09 ±0.02	0.10 ±0.02	.227	0.12 ±0.01	0.13 ±0.02	.480
Glaze						
WT	0.38 ±0.04	0.40 ±0.04	.259	0.37 ±0.04	0.43 ±0.06	.451
CF	0.37 ±0.03	0.43 ±0.04	.030[b]	0.38 ±0.04	0.44 ±0.04	.011[b]
BT	0.38 ±0.02	0.50 ±0.04	.004[b]	0.39 ±0.03	0.45 ±0.05	.112
RW	0.38 ±0.04	0.39 ±0.02	.926	0.37 ±0.05	0.41 ±0.04	.494
CL	0.39 ±0.04	0.40 ±0.04	.721	0.39 ±0.04	0.43 ±0.06	.104
Hardness						
Polishing						
WT	722.75 ±13.1	647.75 ±4.73	.001[b]	725.50 ±5.89	667.25 ±6.00	.001[b]
CF	723.88 ±5.12	664.00 ±5.55	<.001[b]	728.38 ±5.43	673.75 ±5.79	.001[b]
BT	730.38 ±5.59	673.75 ±9.27	.002[b]	734.38 ±9.82	673.63 ±7.57	<.001[b]
RW	732.38 ±10.06	679.13 ±5.97	.007[b]	724.75 ±8.75	651.00 ±5.12	<.001[b]
CL	737.88 ±5.35	675.25 ±5.6	<.001[b]	726.88 ±4.47	659.63 ±5.72	<.001[b]
Glaze						
WT	631.00 ±19.14	589.63 ±7.87	.074	646.25 ±12.08	589.13 ±10.7	.012[b]
CF	655.50 ±14.31	605.63 ±10.15	.001[b]	629.50 ±8.12	588.38 ±9.41	.001[b]
BT	649.25 ±7.79	609.75 ±5.68	.005[b]	662.75 ±19.37	616.00 ±8.38	.030[b]
RW	667.75 ±15.98	611.25 ±6.87	.031[b]	643.38 ±6.93	588.75 ±8.96	.001[b]
CL	650.50 ±11.73	609.00 ±8.79	<.001[b]	654.75 ±8.95	584.63 ±12.9	<.001[b]

BT, black tea; CF, coffee; CL, cola; RW, red wine; WT, distilled water. [a]Paired *t* test. [b]Significant differences (*P*<.05).

highest variation (ΔRa: 0.12 ±0.03). No significant changes were observed for the polished groups (*P*>.05), and all the solutions changed the roughness to the same extent (Tables 2 and 3). A similar trend was observed for the groups subjected to toothbrushing after immersion.

The initial mean VHN was 649.06 ±4.14 for the glazed group and 729.71 ±2.39 for the polished groups, which were statistically different (*P*<.001, independent *t* test). Irrespective of surface treatment, immersion in the tested beverages led to a significant reduction in microhardness (*P*<.05), and this variation (ΔVHN) was similar for all beverages (*P*>.05) (Tables 2 and 3). A multifactorial analysis showed that the decrease in microhardness values after immersion was higher for polished groups (*P*<.001). The same trend was observed for the groups subjected to toothbrushing.

Higher ΔE_{00} values were observed for red wine in both glazed (1.61 ±0.28) and polished (1.91 ±0.36) groups (Table 2); ΔE_{00} values were between the perceptibility and acceptability thresholds. A similar pattern of color change was observed after brushing, with red wine presenting higher ΔE_{00} values (glazed, 1.46 ±0.28; polished, 1.87 ±0.41). The other beverages caused color changes below the perceptibility threshold.

DISCUSSION

Significant changes in surface roughness, microhardness, and color stainability were observed in the CAD-CAM lithium disilicate ceramic after immersion in the tested beverages and were influenced by the type of surface treatment. Brushing was unable to potentiate or diminish these changes. Therefore, the null hypotheses were partially rejected.

The scarcity of studies evaluating the effect of common beverages and toothbrushing on the characteristics of lithium disilicate ceramics may be explained by its excellent physicomechanical stability. Moreover, considering that the method of fabrication of the ceramic restoration could interfere in its properties, few studies have investigated the influence of staining solutions[16-21] and toothbrushing[22] on CAD-CAM lithium disilicate ceramics. The authors are unaware of a previous study evaluating the effect of immersion in common beverages, toothbrushing, and different surface treatments on the surface and micromechanical properties of this type of ceramic.

Highly variable Ra values have been reported for ceramics because they depend on the composition of the material, method of fabrication, measurement methods, and surface treatment.[2,5,7,27] In this study, 2 common

treatments of ceramic surfaces were simulated: glazing application with paste-type glaze, followed by sintering (firing) performed in the laboratory, and mechanical polishing performed with abrasive disks, simulating the esthetic and functional chairside adjustments of the ceramic during clinical evaluation and insertion. The glazed groups presented a mean Ra of 0.38 ±0.01 μm, and the polished groups, 0.10 ±0.00 μm, consistent with the results of previous studies evaluating different polishing systems for ceramics.[3,5,24,26] These results show that mechanical polishing can provide low Ra values for CAD-CAM lithium disilicate restorations, with the potential for reducing microbial adhesion and the mechanical retention of extrinsic substances.[2,7]

The highest changes in roughness values observed in the glazed groups may be related to the higher initial mean roughness value, favoring the accumulation of extrinsic substances[3] differently from the polished groups. Different mechanical polishing systems are considered advantageous in comparison with glazing regarding roughness and have achieved adequately smooth and polished surfaces.[2,4] In the present study, the polished groups maintained their roughness almost unchanged, demonstrating the value of this procedure. The most significant changes in the glazed groups immersed in coffee and in black tea may be explained by the low pH and elevated temperatures, factors that may affect the mechanical and physical properties of ceramics.[8,14] Moreover, the acid pH of these solutions may dissolve silica, with a consequent loss of alkaline ions and corrosion of the surface,[9,14] which may have potentiated the degradation of the glaze and led to an increase in roughness.

CAD-CAM lithium disilicate was shown to present higher Vickers microhardness mean values (617 VHN)[28] than other CAD-CAM ceramics; this matches well with values in the present study. Although greater reduction in microhardness was demonstrated for the polished groups, their final VHNs were close to the initial values in the glazed groups, both higher than that of tooth enamel (347 VHN). Glazing has been said to reduce the hardness of the ceramic surface and may result in the benefit of less wear on the antagonist substrates.[27,28] However, irrespective of whether the ceramic was glazed or polished, significant changes were observed in this property. This effect possibly occurred because of dissolution of the silica network through the action of H_3O^+ and OH^- ions and the H_2O molecules that act by rupturing the silica molecules (Si-O-Si)[15] and selective leaching of alkaline ions; these mechanisms appear to occur in combination.[9,15] The loss of elements such as Si, Al, Na, K, and Zr from the ceramic material has been reported.[9]

Although CAD-CAM lithium disilicate is considered a color-stable material,[19] perceptible color changes were detected in the present study after immersion in common beverages. Irrespective of surface treatment, red wine caused higher ΔE_{00} values, in agreement with previous studies.[1,16,19] Thus, both glazing and mechanical polishing allowed perceptible color changes to occur. In addition to alcohol as an agent with the potential for degradation, the higher level of staining by red wine appears to be related to the high polarity of the substance and its coloring agents, promoting more intense adsorption at the surface and penetration into the material.[14] Mean ΔE_{00} values below the perceptibility threshold were found for other beverages in accordance with previous studies evaluating similar conditions.[17-21] Longer immersion periods may cause more significant changes.

Similarity in the staining pattern was observed irrespective of surface treatment, suggesting that adequate chairside mechanical polishing could be as effective as laboratory glazing. Only 1 study found higher ΔE_{00} values when a mechanically polished CAD-CAM monolithic lithium disilicate was subjected to a colored beverage (coffee) in comparison with a glazed ceramic; the color change was below the perceptibility threshold.[21] Lawson and Burgess[18] reported low ΔE_{00} values (mean 0.17 ±0.08) for the same brand of ceramic polished by using grinding papers after immersion in a staining solution containing coffee, black tea, and juice.

In addition to the limited number of studies on the effect of toothbrushing on CAD-CAM lithium disilicate,[22] the question raised could be whether the changes caused by the beverages could have been easily influenced by the associated action of brushing. No significant color changes were found when this material was subjected to toothbrushing for a simulated period of 15 years.[22] Thus, in the present study, toothbrushing was performed after immersion in the solutions to observe its effects on the changes found.

Toothbrushing could help remove staining or even the accumulation of substances weakly adhered to the material surface. Irrespective of surface treatment, brushing did not significantly change the staining or degradation caused by the solutions, suggesting that the changes observed occurred at a structural and permanent level. In a previous study,[10] toothbrushing led to color differences in a lithium disilicate (e.max Press), which was found only after simulation of a period of 12 years; however, the changes were not clinically relevant. Moreover, the authors reported a possible protective effect provided by the glaze, which was perhaps responsible for the lower effect of brushing on the ceramic. Thus, the present study suggested that adequate mechanical polishing could protect ceramic against brushing, comparable with the effect of glazing.

The results of the present study suggested that mechanical polishing of CAD-CAM lithium disilicate restorations could produce a surface with desirable properties, allowing the dentist to make chairside adjustments before or after cementation without an additional glazing

procedure, thereby avoiding an additional clinical session. Future studies could evaluate the same tested conditions by comparing different CAD-CAM materials, thicknesses, and degrees of translucency. In the present study, the high-translucent ceramic was chosen because of its extensive application for esthetic restorations such as laminate veneers in anterior teeth. Nevertheless, the in vitro design represents an important limitation because it was conducted in an environment that did not fully reflect the clinical situation. Thus, long-term clinical studies are necessary to support the conclusions.

CONCLUSIONS

Within the limitations of this in vitro study, the following conclusions were drawn:

1. The glazed groups presented higher surface roughness and lower microhardness values than mechanically polished groups.
2. Surface roughness increased in all groups after immersion in the tested beverages, and this effect was more considerable in the glazed groups. Black tea caused the most change.
3. Microhardness decreased after immersion in all tested beverages, irrespective of the type of surface treatment.
4. In both glazed and polished groups, most beverages led to color changes below the perceptibility threshold ($\Delta E_{00} < 1.30$). Red wine caused the most change, with ΔE_{00} mean values ranging between the perceptibility and acceptability threshold values ($\Delta E_{00} < 2.25$).
5. The toothbrushing performed was unable to potentiate or diminish the effects of the test beverages for any of the properties evaluated.

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