BJOS Brazilian Journal of Oral Sciences

Original Research

Volume 25
2026
e267776

Effect of sensitivity and whitening toothpastes on roughness and microhardness of esthetic CAD-CAM restorative materials

Gladys Juanita Teresa Purizaga Patiño[1], Elim Karine da Silva de Oliveira[1], Aline Cristina Batista Rodrigues Johann[1], Luciana Reis Azevedo-Alanis[1], Evelise Machado de Souza[1], Rodrigo Nunes Rached[1]*

[1] School of Medicine and Life Sciences, Pontifícia Universidade Católica do Paraná (PUCPR), Curitiba, PR, Brazil.

Aim: To assess the impact of brushing using 5 different toothpastes on the roughness and microhardness of CAD-CAM materials. **Methods:** A total of 400 specimens (14 × 5 × 2.5 mm) were fabricated using four different materials: 2 resin composites (Lava Ultimate, LU; Cerasmart, CE), 1 polymer-infiltrated ceramic (Vita Enamic, VE), and 1 lithium disilicate glass-ceramic (IPS e.max CAD, EM). Twenty specimens of each material were brushed (100,000 cycles) using three types of toothpastes: 1 regular (Colgate Total 12, CT), 2 sensitivity (Sensodyne Pro-Enamel, SP; Colgate Sensitive Pro-Relief, CS), and 2 whitening (Oral-B 3D White, OB; Colgate Luminous White, LW). Surface roughness (Ra) and microhardness (KHN) were measured before and after brushing. The data were submitted to the Kruskal-Wallis test followed by the Bonferroni-Dunn multiple comparison and Wilcoxon tests (α=.05). **Results:** For CE, the post-brushing Ra using SP was significantly lower (P=.017) than the other toothpastes. For EM, the post-brushing Ra using SP was significantly higher than CS (P=.017). In general, the toothpastes increased the material Ra (P<.02), except for SP, which decreased the Ra of LU and CE (P<.007) and had no effect on VE (P>.05). Only CE brushed using LW showed an Ra higher than 0.2 µm. KHN did not differ among toothpastes within each material before or after brushing. The sensitivity toothpastes significantly increased KHN values of all materials after brushing, while a significant reduction was observed with the other toothpastes (P<.05). **Conclusions:** Sensitivity toothpastes decreased surface roughness of the resin composites LU and CE and increased hardness of all other materials. Regular and whitening toothpastes increased surface roughness and decreased hardness of most restorative materials.

Keywords: Computer-aided design. Toothpastes. Toothbrushing. Hardness.

Corresponding author:
Rodrigo Nunes Rached
Graduate Program in Dentistry, School of Medicine and Life Sciences, Pontifícia Universidade Católica do Paraná (PUCPR), Rua Imaculada Conceicao 1155, Curitiba, PR, 80215-901, Brazil
e-mail: r.rached@pucpr.br

Editor: Dr. Altair A. Del Bel Cury

Received: September 10, 2024
Accepted: September 12, 2025

Introduction

Abrasion of restorative material resulting from brushing can be considered a major factor in increasing the surface roughness of enamel[1-3], composite resin restorations[4-6], and CAD-CAM composites[4,7,8]. The surface properties of CAD-CAM materials may change over time, depending on the composition, size, and morphology of the particles[5,9]. In addition, intraoral deterioration resulting in material wear due to parafunctional habits, types of food, and oral hygiene are factors to be considered[5,10,11].

Excessive brushing combined with use of an abrasive particle-containing toothpaste can increase the surface roughness of esthetic restorative materials[5,11-13]. Commercially available sensitivity and whitening toothpastes are formulated to contain abrasives such as alumina, sodium bicarbonate, silica, calcium carbonate, and pyrophosphates[14-17]. The effects of continuous and frequent application of these particles on the surface integrity of teeth and restorations from tooth brushing is a cause for concern[12,15-22].

A high roughness surface tends to increase staining and decrease restoration gloss. These changes compromise aesthetics[5,9,23,24], facilitating biofilm formation and accumulation of bacterial plaque. Such accumulation can lead to gingival inflammation and secondary caries[9,23,25-27], as well as cause wear to the opposing dentition[9,23]. In addition to roughness, toothpastes can also affect the physical properties of CAD-CAM composite resins such as surface microhardness. This property is important for evaluating composite characteristics related to wear resistance[7,9,28].

Glass ceramics, polymer-infiltrated ceramic, and CAD-CAM composite resin materials are used to fabricate inlays, onlays, crowns, and fixed bridges[28,29]. Glass ceramics are formed by a glass matrix and a crystalline phase and can be classified into feldspathic ceramics, leucite-reinforced ceramics, lithium disilicate, and zirconia-reinforced lithium silicate ceramics[30,31]. Resin composite materials are formed by combining an organic resin matrix and inorganic fillers[7,32]. Polymer-infiltrated ceramic materials are composed of a pre-sintered glass ceramic phase infiltrated with a resin-based organic matrix[31,32]. The resin-infused ceramic materials are polymerized under high temperature and pressure[4,10,32], resulting in high degree of polymer conversion and superior properties compared to direct resin composites[7,29,33].

Studies that evaluated the roughness[4,5,7,11,23,30] and microhardness[4,7,23,30] of CAD-CAM materials after brushing tested only one single type of dentifrice. The effect of toothpastes with different abrasive potential on CAD-CAM restorative materials needs further investigation. Thus, the purpose of this in vitro study was to study changes in surface roughness and microhardness of CAD-CAM restorative materials submitted to artificial brushing using a variety of toothpaste types: regular, sensitivity and whitening. The null hypotheses were that the type of material and toothpaste would have no significant influence on the surface roughness and microhardness of the tested materials.

Material and Methods

Four esthetic CAD-CAM materials were tested: 2 resin composites, 1 polymer-infiltrated ceramic, and 1 lithium disilicate glass-ceramic. The commercial brand and composition of each material are shown in Table 1.

Table 1. CAD-CAM materials used and their composition (manufacturer-supplied)

CAD-CAM Material	Manufacturer	Type	Composition
Lava Ultimate	3M ESPE	Nanoceramic Resin composite	80%weight nanoceramic and 20%weight resin matrix. SiO_2 fillers (20 nm), 31%weight ZrO_2 (4-11 nm), ZrO_2/SiO_2 (0.6-10 μm) nanoclusters, dispersed in a Bis-GMA, UDMA, Bis-EMA, TEGDMA matrix
Cerasmart	GC America	Resin composite	Bis-MEPP, UDMA, DMA. Silica (20 nm), Barium Glass (300 nm), 64 %weight filler
Vita Enamic	Vita Zahnfabrik	Polymer-infiltrated ceramic	Feldspathic ceramic network (86 %weight) infiltrated by UDMA and TEGDMA organic matrix
IPS e.max CAD	Ivoclar Vivadent AG	Lithium disilicate ceramic	SiO_2, Li_2O, K_2O, P_2O_5, ZrO_2, ZnO, Al_2O_3, MgO

BisEMA, ethoxylated bisphenol A dimethacrylate; BisGMA, bisphenol A-glycidyl methacrylate; BisMEPP, bisphenol a ethoxylate dimethacrylate; DMA, dimethyl methacrylate; TEGDMA, triethylene glycol dimethacrylate; UDMA, urethane dimethyl methacrylate.

Table 2. Toothpastes used and their composition (manufacturer-supplied)

Toothpaste	Code used in manuscript	Composition
Sensodyne Pronamel (Sensitivity toothpaste)	SP	Sodium fluoride 0.315% w/w, potassium nitrate 5% w/w, water, sorbitol, hydrated silica, glycerin, PEG-6, Cocamidopropyl betaine, xanthan gum, sodium saccharin, titanium dioxide, sodium hydroxide, flavoring, d-limonene, and anise alcohol
Colgate Sensitive Pro-Relief (Sensitivity toothpaste)	CS	Arginine (8%), sodium monofluorophosphate (1.1%), calcium carbonate, water, sorbitol, arginine bicarbonate, sodium lauryl sulfate, sodium monofluorophosphate, flavor/flavoring, cellulose gum, sodium bicarbonate, tetrasodium pyrophosphate, sodium saccharin, benzyl alcohol, xanthan gum, titanium dioxide (CI 77891), limonene
Colgate Total 12 (Regular toothpaste)	CT	Sodium fluoride (0.32%), glycerin, water, hydrated silica triclosan (0.3%), water, sorbitol, hydrated silica, sodium lauryl sulfate, arginine, flavor, cellulose gum, zinc oxide, Poloxamer 407, tetrasodium pyrophosphate, zinc citrate, benzyl alcohol, xanthan gum, Cocamidopropyl betaine, sodium fluoride, sodium saccharin, phosphoric acid, sucralose, titanium dioxide (CI 77891)
Oral-B 3D White (Whitening toothpaste)	OB	Sodium fluoride, water, sorbitol, hydrated silica, disodium pyrophosphate, sodium lauryl sulfate, cellulose gum, aroma, sodium hydroxide, sodium saccharin, carbomer, mica (CI 77091), limonene, titanium dioxide (CI 77891), sodium benzoate, potassium sorbate, polyethylene (CI 42090), sodium saccharin, citric acid
Colgate Luminous White (Whitening toothpaste)	LW	Sodium fluoride (0.32%) water, sorbitol, hydrated silica, PEG-12, sodium lauryl sulfate, flavor, cellulose gum, potassium hydroxide, tetrasodium pyrophosphate, phosphoric acid, Cocamidopropyl betaine, sodium fluoride, benzyl alcohol, sodium saccharin, titanium dioxide (CI 77891), limonene

A total of 400 specimens were prepared, with 100 specimens for each material (n=20). Half of the specimens (n=10) were used for surface roughness testing, while the other half were used for Knoop microhardness testing.

Blocks of commercial CAD-CAM materials were sectioned into bars (14 × 5 × 2.5 mm) using a low-speed diamond disc mounted on a precision cutting machine (IsoMet 1000 Precision Cutter, Buehler, Lake Bluff, IL, United States), under abundant water cooling. The sectioned specimens were then fixed to Teflon molds (Fig. 1) and polished using silicon carbide abrasives with grit sizes of 600 (30 seconds), 800 (60 seconds), and 1200 (120 seconds) on a polishing machine (Aropol 2 V, Arotec, Coita, SP, Brazil) under water irrigation. Between each abrasive paper change, the specimens were cleaned in an ultrasonic bath for 10 minutes to remove any debris and then dried with an air jet for 20 s. Prior to fixation in Teflon molds, all ceramic specimens (IPS e.max CAD, Ivoclar Vivadent AG, Schaan, Liechtenstein) were crystallized/sintered according to the manufacturer's instructions.

Figure 1. CAD-CAM restorative material specimens previously sectioned and attached to a Teflon mold.

The specimens of the 4 materials and the 5 toothpaste types were randomly distributed into 5 groups (n=10) following a randomization table (Excel; Microsoft Corp) listing all possible treatment combinations. The initial surface roughness value (Ra) of each block (n = 10) was determined using a profilometer (Talyscan 150, Taylor Hobson, Leicester, United Kingdom), having a trace length of 1.5 mm, a trace speed of 500 μm/s, and a cut-off length of 0.25 μm. Three parallel measurements, each spaced 400 μm apart, were made perpendicular to the 6-mm long brushing direction. The Ra value for a given specimen was calculated as the average of the 3 measurements. The initial surface microhardness of the second set of specimens (n = 10) was evaluated using a microhardness tester (HMV, Shimadzu, Kyoto, Japan) with a Knoop diamond indenter and applying a load of 300 gf for a dwell time of 15 s. Five indentations were made on each specimen, spaced at least 1 mm apart. The average value of the 5 random measurements was used for the statistical analysis.

After the initial measurements of surface roughness and hardness, the ends of the specimens (4 mm on each side) that underwent roughness testing were covered with a metal sheet and PVC tape (Fig. 1). Then, the specimens were mounted on an artificial brushing machine (MEV 2-T, Odeme Dental Research, Luzema, SC, Brazil), set to provide brushing strokes of 60 mm in length at a frequency of 2 Hz: one "cycle" consisting of a forward and backward stroke. A vertical force of 2 N was applied to the toothbrushes (Soft Adult Toothbrush - Slide Pro, Medfio, São José dos Pinhais, PR, Brazil) during testing. The specimens and toothbrushes were immersed in containers with one type of toothpaste (Fig. 2), prepared with 4 g of toothpaste and 8 mL of distilled water (proportion of 1:2)[6,11,17]. The specimens were subjected to 100,000 brushing cycles. The toothpaste slurry was periodically changed every 20,000 cycles. To minimize the effect of location, each combination of material and toothpaste underwent testing at every brush machine location. After completing the brushing cycles, the specimens were cleaned in an ultrasonic cleaner for 10 minutes and then the surface roughness and hardness were measured again.

Figure 2. Brushing machine with specimens in place.

Two representative specimens from each test group were analyzed using scanning electron microscopy (SEM) after toothbrush testing. Both the area that was protected with metallic paper (control) and the area that was brushed were analyzed. The specimens were coated with gold and examined using SEM at a voltage of 20kV and a magnification of ×1,000 (Tescan Orsay Holding, a.s, Kohoutovice, Czech Republic).

A statistical software program (IBM SPSS Statistics, v24.0, IBM Corp, Armon, NY, United States) was used for all data analyses (α=0.05 for all tests). Microhardness and roughness data were found not to be normally distributed (Shapiro-Wilk, P<.05) and thus non-parametric analytical methods were applied: the Kruskal-Wallis non-parametric test. Comparisons of surface roughness and microhardness between toothpastes for each material before and after brushing were made using the Bonferroni-Dunn multiple comparison test. Comparisons of data before and after brushing for each group were made using the Wilcoxon paired comparisons test. The analyses of percentage change in microhardness and roughness were performed using absolute data. A power analysis (>99%) based on the ranked data of roughness and microhardness data showed the sample size was appropriate.

Results

The initial values of roughness and microhardness for each material are presented in Table 3. The initial roughness of Vita Enamic and IPS e.max CAD were significantly lower than those of Lava Ultimate and Cerasmart (*P* <.001). There were no significant differences within these two pairs (*P* >.05). IPS e.max CAD showed the highest initial microhardness, while Cerasmart had the lowest (*P*<.001).

Table 3. Median (minimum-maximum) values of initial roughness and Knoop microhardness for each material

Material	Initial Roughness (microns)	Initial Microhardness (KHN)
Lava Ultimate	0.045 (0.037-0.059) [a]	71.74 (68.06-78.22) [c]
Cerasmart	0.043 (0.003-0.060) [a]	50.79 (47.16-55.80) [d]
Vita Enamic	0.032 (0.025-0.045) [b]	153.00 (138.80-175.20) [b]
IPS e.max CAD	0.027 (0.011-0.041) [b]	501.90 (387.60-532.80) [a]

Within each column, the median values identified using the same lower-case letters are not significantly different (Bonferroni-Dunn multiple comparison tests, *P*>.05).

The initial and post-brushing roughness results are presented in Table 4. The toothpaste type significantly affected roughness for 2 material types. For Cerasmart, the post-brushing roughness using SP toothpaste was significantly lower (*P*=.017) than that of using CT (*P*<.002), OB (*P*<.001), and LW (*P*<.001), but no difference was noted for CS. For IPS e.max CAD, the post-brushing roughness using SP toothpaste was significantly higher (*P*=.017) than that of using CS. There were significant differences between the initial and post-brushing roughness for all toothpastes and materials separately, except for CS with Cerasmart, SP with Vita Enamic, and CS, CT, and OB with IPS e.max CAD (*P*>.05). While most toothpastes increased Ra (*P*<.02), SP decreased Ra in Lava Ultimate (*P*<.007) and Cerasmart (*P*<.005) but had no effect on Vita Enamic (*P*>.05). Only Cerasmart brushed with LW showed a median Ra higher than 0.2 μm.

Table 4. Median (minimum-maximum) values of initial and post-brushing roughness (Ra) for restorative materials and toothpastes

Material	Toothpaste	Median Roughness (microns)		P-value*
		Initial	Post-brushing	
Lava Ultimate	SP	0.043 (0.040-0.055)	↓0.039 (0.038-0.042)	0.007*
	CS	0.042 (0.037-0.056)	↑0.051 (0.040-0.065)	0.011*
	CT	0.042 (0.037-0.055)	↑0.069 (0.038-0.081)	0.008*
	OB	0.052 (0.042-0.059)	↑0.060 (0.054-0.077)	0.008*
	LW	0.050 (0.037-0.055)	↑0.075 (0.047-0.154)	0.005*

Continue

Continuation

Cerasmart	SP	0.044 (0.037-0.055)	↓0.031 (0.021-0.044) $	0.005*
	CS	0.042 (0.030-0.060)	0.051 (0.031-0.089)	0.107
	CT	0.043 (0.035-0.051)	↑0.104 (0.042-0.402) $	0.007*
	OB	0.042 (0.036-0.055)	↑0.115 (0.051-0.271) $	0.005*
	LW	0.048 (0.033-0.060)	↑●0.268 (0.110-0.606) $	0.005*
Vita Enamic	SP	0.029 (0.026-0.041)	0.037 (0.021-0.058)	0.153
	CS	0.035 (0.027-0.043)	↑0.044 (0.038-0.051)	0.008*
	CT	0.034 (0.025-0.045)	↑0.045 (0.033-0.084)	0.005*
	OB	0.031 (0.027-0.040)	↑0.042 (0.036-0.081)	0.007*
	LW	0.031 (0.025-0.042)	↑0.056 (0.035-0.201)	0.005*
IPS e.max CAD	SP	0.036 (0.018-0.041)	↑0.058 (0.038-0.094) #	0.005*
	CS	0.031 (0.015-0.041)	0.018 (0.012-0.048) #	0.065
	CT	0.026 (0.014-0.040)	0.036 (0.016-0.076)	0.066
	OB	0.028 (0.016-0.041)	0.025 (0.018-0.096)	0.646
	LW	0.019 (0.011-0.039)	↑0.033 (0.021-0.053)	0.015*

* Statistically significant differences between initial and post-brushing roughness (Wilcoxon paired comparisons test, *P*<.05).
Symbol prior to post-brushing median value indicates statistically higher (↑) or lower (↓) roughness compared to pre-brushing state.
● symbol indicates post-brushing surface roughness > 0.20 microns
$ After brushing, the roughness of Cerasmart was significantly lower for SP compared to CT (*P*<.002), OB (*P*<.001), and LW (*P*<.001), which did not differ from each other (*P*>.05) (Bonferroni-Dunn multiple comparison tests, *P*>.05).
# After brushing, the roughness of IPS e.max CAD was significantly higher for SP compared to CS (*P*=.017) (Bonferroni-Dunn multiple comparison tests, *P*>.05).
SP, Sensodyne Pronamel; CS, Colgate Sensitive Pro-Relief; CT, Colgate Total 12; OB, Oral-B 3D White; LW, Colgate Luminous White.

The initial and post-brushing microhardness results are presented in Table 5. For each restorative material, microhardness values were not significantly different within initial values or within post-brushed values (*P*>.05). However, there was a significant difference between initial and post-brushing microhardness for all groups. Sensitivity toothpastes (SP and CS) increased the KHN values in all materials after brushing, while regular (CT) and whitening toothpastes (OB and LW) reduced the microhardness values for all restorative materials (*P*<.05).

Table 5. Median (minimum-maximum) values of initial and post-brushing microhardness (KHN) for each evaluated material and toothpaste

Material	Toothpaste	Median Knoop Microhardness		P-value*
		Initial	Post-brushing	
Lava Ultimate	SP	71.05 (68.06-75.80)	73.49 (69.86-76.70)	0.005
	CS	70.61 (68.14-75.08)	73.75 (69.16-79.24)	0.005
	CT	71.74 (69.22-74.28)	68.99 (64.96-74.24)	0.007
	OB	72.13 (69.44-78.22)	69.78 (67.88-72.78)	0.005
	LW	71.3 (70.18-75.92)	69.49 (66.04-70.18)	0.005
Cerasmart	SP	50.02 (47.16-52.64)	52.81 (48.32-55.88)	0.005
	CS	49.53 (48.32-52.06)	51.69 (50.64-56.10)	0.005
	CT	50.79 (47.62-55.80)	47.77 (45.72-52.28)	0.005
	OB	51.06 (48.86-53.16)	49.57 (47.72-53.64)	0.009
	LW	50.81 (48.28-54.28)	47.73 (42.34-49.62)	0.005
Vita Enamic	SP	151.3 (140.0-175.2)	160.8 (155.0-169.4)	0.037
	CS	152.7 (138.8-167.6)	154.4 (146.8-173.8)	0.017
	CT	152.7 (150.2-165.0)	148.6 (142.6-158.8)	0.047
	OB	152.8 (150.6-165.8)	145.8 (141.2-160.6)	0.007
	LW	155.6 (151.4-163.4)	145.9 (129.6-160.0)	0.009
IPS e.max CAD	SP	468.1 (387.6-496.6)	489.5 (422.0-509.2)	0.005
	CS	483.8 (448.6-518.6)	495.8 (477.2-546.0)	0.022
	CT	506.6 (453.6-518)	468.8 (427.4-486.8)	0.005
	OB	506.1 (447-524.6)	464.5 (428.0-495.2)	0.007
	LW	507.2 (489.8-532.8)	475.1 (421.0-508.2)	0.005

* Statistically significant difference between initial and post-brushing hardness, Wilcoxon's paired comparison test. SP, Sensodyne Pronamel; CS, Colgate Sensitive Pro-Relief; CT, Colgate Total 12; OB, Oral-B 3D White; LW, Colgate Luminous White.

There were no significant differences in percentage change of roughness (Fig. 3) or microhardness (Fig. 4) between materials brushed using the same toothpaste (P>.05). With respect to differences between toothpastes within each restorative material, Cerasmart showed significantly higher roughness after LW (5.1%) brushing compared to SP (-0.3%) and CS (0.24%) brushing (Fig. 3) (P<.001). No significant differences in percentage change in microhardness (Fig. 4) among toothpastes were found within restorative material types (P>.05). In general, sensitivity toothpastes (SP and CS) showed negative percentage change values for roughness for Lava Ultimate, Cerasmart, and IPS e.max CAD (Fig. 4). Regular (CT) and whitening toothpastes (OB and LW) showed negative percentage change values for microhardness in all materials (Fig. 4).

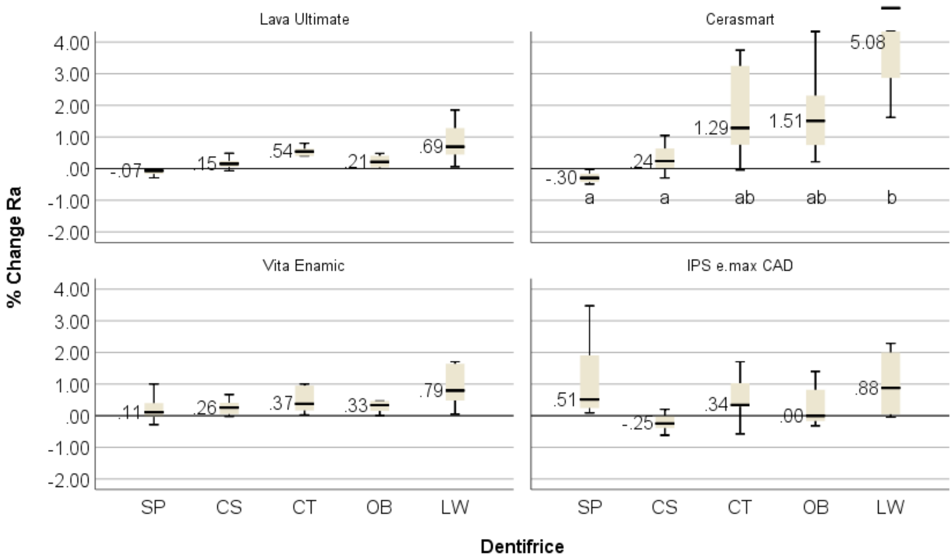
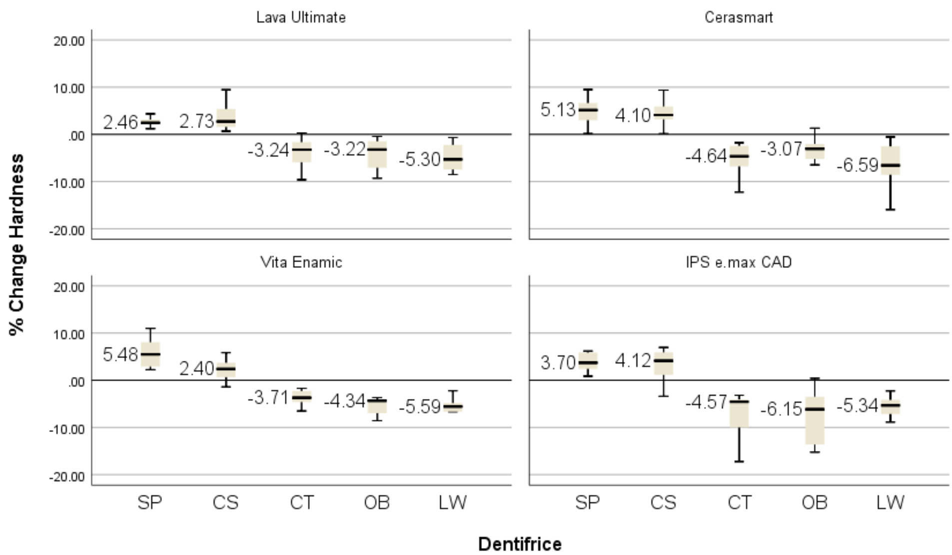


Figure 3. Boxplots of the percentage change in roughness (medians, interquartile range, and highest and lowest data points). For Cerasmart, SP and CS showed significantly lower values than LW (boxes connected by different letters, *P*=.002; *P*=.007). For all other materials, there were no significant differences between toothpastes, and there were no significant differences between materials brushed with the same toothpaste (Bonferroni-Dunn multiple comparison tests, *P*>.05). SP, Sensodyne Pronamel. CS, Colgate Sensitive Pro-Relief. CT, Colgate Total 12. OB, Oral-B 3D White. LW, Colgate Luminous White.



SP, Sensodyne Pronamel. CS, Colgate Sensitive Pro-Relief. CT, Colgate Total 12. OB, Oral-B 3D White. LW, Colgate Luminous White.

Figure 4. Boxplots of the percentage change in hardness results (medians and interquartile range). For each material, there were no significant differences between toothpastes, and there were no significant differences between materials brushed with the same toothpaste (Bonferroni-Dunn multiple comparison tests, *P*>.05).

The SEM images of each material before and after brushing are shown in Figures 5-8. After brushing using regular (CT) and whitening toothpastes (OB and LW), the images suggest formation of surface irregularities: cracks, dislodgement of filler particles, perforations, and deep grooves parallel to the brushing direction (Figs. 5-8). After brushing using SP, small grooves parallel to the brushing direction became evident in Lava and IPS e.max CAD (Figs. 5 and 8).

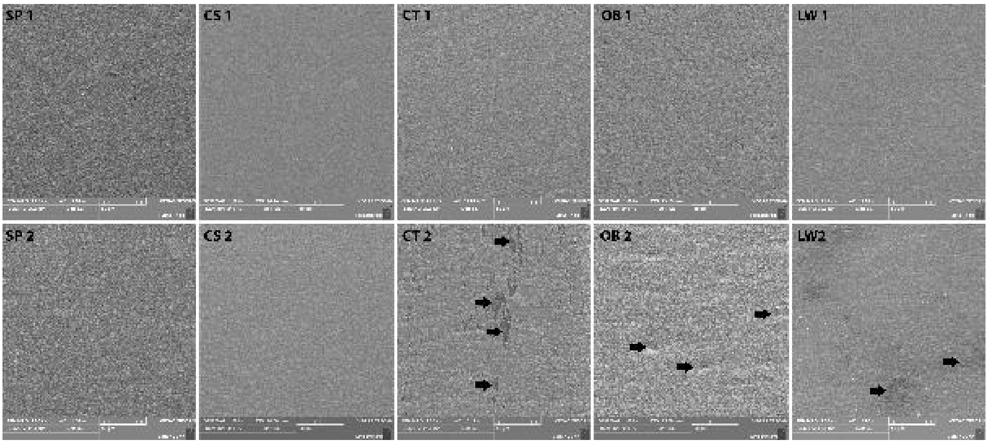


Figure 5. Representative SEM images of the Lava Ultimate material, with a magnification of ×1000, from a before (1) and after brushing (2) using sensitivity (SP and CS), regular (CT), or whitening (OB and LW) toothpastes. The black arrows point to the cracks or scratches caused by brushing.

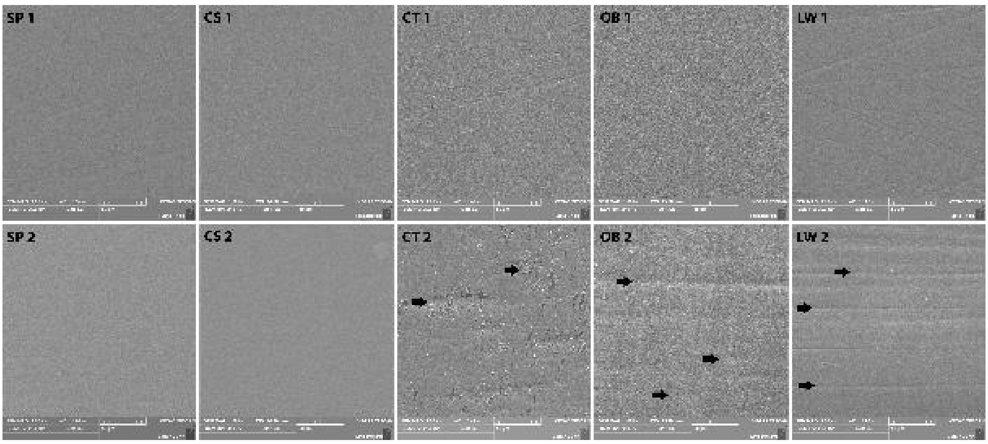


Figure 6. Representative SEM images of the Cerasmart material, with a magnification of ×1000, from before (1) and after brushing (2) with sensitivity (SP and CS), regular (CT), and whitening (OB and LW) toothpastes. The black arrows point to the cracks or scratches caused by brushing.

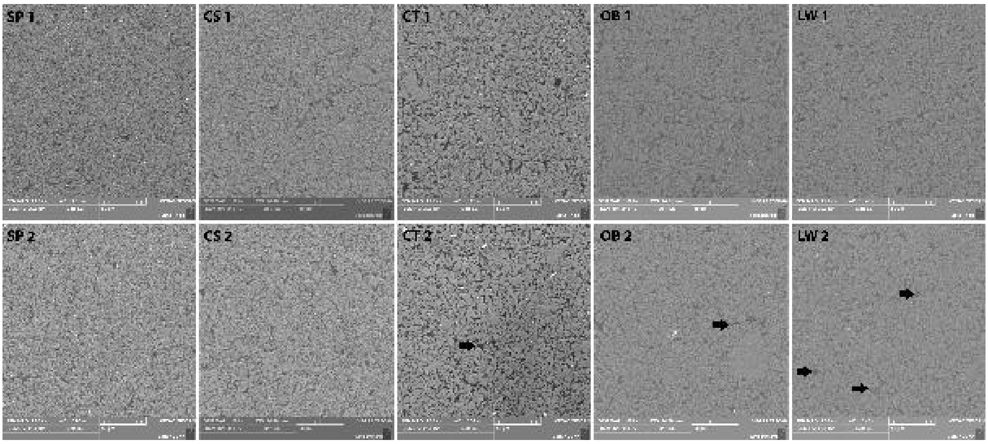


Figure 7. Representative SEM images of the Vita Enamic material, with a magnification of ×1000, from before (1) and after brushing (2) with sensitivity (SP and CS), regular (CT), and whitening (OB and LW) toothpastes. The black arrows point to the cracks or scratches caused by brushing.

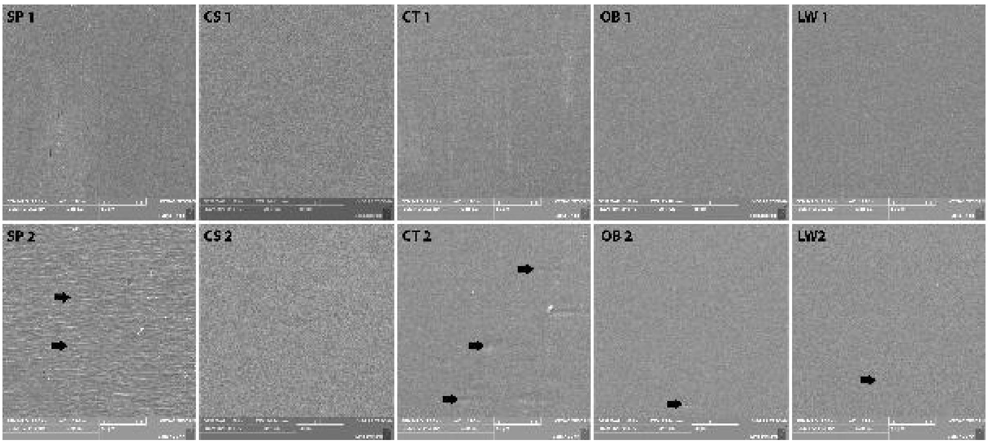


Figure 8. Representative SEM images of the IPS material e.max CAD, with a magnification of ×1000, from before (1) and after brushing (2) with sensitivity (SP and CS), regular (CT), and whitening (OB and LW) toothpastes. The black arrows point to the cracks or scratches caused by brushing.

Discussion

Mean surface roughness (Ra) is a commonly used parameter in brushing studies due to its significant positive correlation with bacterial adhesion[25]. A critical threshold value for bacterial adhesion is an average roughness of 0.2 μm[8,16,26]. Additionally, to ensure patient comfort, the surface roughness of restorative materials should be similar to or lower than that of intact tooth enamel, which has a surface roughness of 0.64 μm[6,16]. In this study, only Cerasmart brushed using LW showed a median Ra value higher than 0.2 μm, and repolishing would be clinically indicated for this material.

Before brushing, IPS e.max CAD and Vita Enamic exhibited the lowest roughness values, while Lava Ultimate and Cerasmart the highest ones. There were no significant differences between the materials of each pair. In a previous study, IPS e.max CAD showed lower roughness values than Lava Ultimate and Vita Enamic[34]. A similar roughness has also been found between Lava Ultimate and Cerasmart before brushing[7].

In the present study, the type of toothpaste showed a significant effect on the surface properties of Cerasmart and IPS e.max CAD materials. One sensitivity toothpaste (SP) showed lower roughness than the regular and whitening toothpastes for Cerasmart. The surface roughness of Cerasmart appears to be more affected by toothbrushing than that of other materials[7,11,23]. In addition to the composition and quantity of abrasives in the toothpastes, the size and shape of these particles affect the roughness of the brushed surface[1,14,16,17,21,27]. Previous studies tested toothpastes with Relative Dentine Abrasiveness (RDA) values ranging from 44 to 136 and found increased surface roughness of CAD-CAM composite resin materials after toothbrushing[4,7,11,23,30]. The sensitivity and whitening toothpastes were included in this study because previous research tested only one toothpaste each. Unfortunately, manufacturers of many toothpastes do not provide RDA values or an explanation of possible wear effects of the toothpastes on restorative materials.

The sensitivity toothpastes (SP and CS) decreased or did not affect restorative material surface roughness in some groups. The quantities of abrasive particles present on these toothpastes are lower than those in regular and whitening toothpastes[19,27]. Also, sensitivity toothpastes may have caused slight wear on the surface materials, leaving a surface with smaller and more homogeneous fillers, resulting in a decrease in surface roughness[24]. Colgate Total 12 has been frequently tested in previous studies[5,13,30]. This toothpaste has lower abrasiveness than whitening toothpastes[13] and higher abrasiveness than sensitivity toothpastes[19]. Whitening toothpastes tend to be more abrasive because they contain a higher amount of abrasive particles aimed at removing extrinsic stains from enamel[16,17]. In the present study, the whitening toothpastes increased surface roughness in most restorative materials. These results corroborate previous findings that the mechanism of action of whitening toothpastes is mainly based on the presence of high amounts of abrasives. While the abrasive action can effectively remove surface stain[20], another study evaluated the wear of dentin with the use of toothpaste and detergents and found that brushing with the use of detergents caused wear on the dentin due to a direct chemical attack on the organic material[21]. Unfortunately, no research was found that evaluated the effect of detergents contained in toothpaste on the surface of restorative materials.

Material groups brushed using regular or whitening toothpastes showed higher roughness values than the baseline values for Lava Ultimate, Cerasmart, and Vita Enamic groups. SEM images show traces of brushing through the formation of deep grooves and scratches, due to a displacement of filler particles, which produced an increase in surface roughness. These results confirm that regular and whitening toothpastes were more abrasive than sensitivity toothpastes for the resin composites and the polymer-infiltrated ceramic. For IPS e.max CAD, only one whitening toothpaste (LW) showed an increase in roughness after brushing. This result may be related to the strong ceramic network structure and higher microhardness values of IPS e.max

CAD[11]. A previous study also reported that brushing with a toothbrush alone did not significantly increase surface roughness[22]. However, due to the retention of the abrasive agents within the bristles of the toothbrush, brushing with a toothpaste could affect the surface structure[1,22].

This study showed that IPS e.max CAD had the highest microhardness before brushing, followed by Vita Enamic, Lava Ultimate, and Cerasmart. These findings are corroborated in a previous study in which IPS e.max CAD showed significantly higher microhardness compared to Vita Enamic and Lava Ultimate[34]. Other studies also reported higher microhardness values of Vita Enamic compared to Lava Ultimate and Cerasmart[7,28,30], which indicates that the surface properties of Vita Enamic are intermediate between composites and CAD-CAM ceramics[23,35]. These results may be related to material composition, including the type, size, and shape of inorganic fillers, and the polymer matrix[7]. Cerasmart contains alumina, barium, and silicate in the form of small, uniformly distributed particles, while Lava Ultimate is composed of a wide range of particle sizes of silica and zirconia[28]. Vita Enamic has a dense network structure composed of potassium-alumina-silicate and small particles of yttrium-silicate[28]. IPS e.max CAD contains approximately 70% lithium disilicate crystals in a glass matrix[34]. The higher surface hardness of Vita Enamic and IPS e.mac CAD materials may be attributed to their strong ceramic structure and genera; resistant to changes from brushing[11].

In the present study, the sensitivity toothpastes (SP and CS) showed the highest percentage microhardness value changes for the CAD-CAM materials. This finding may be related to the protection against erosion-abrasion challenges provided by sensitivity toothpastes[1,19], which have minerals that react in aqueous environments to release arginine, calcium ions, phosphate, and/or sodium. This interaction may have resulted in an accumulation of these ions in the surface of the specimens, filling microscopic defects in the CAD-CAM materials and leading to an increase in surface microhardness[3,12]. The finding may also be related to a removal of the surface layer of the organic matrix with exposure of particles harder than the organic portion [27].

On the other hand, the whitening toothpastes (OB and LW) resulted in a lowering of microhardness values for all materials tested. Whitening toothpastes are known to contain abrasive agents, hydrated silica, and pyrophosphates, which are designed to remove extrinsic stains from the tooth surface[17]. Brushing using toothpastes having such abrasive particles may have displaced inorganic particles from the CAD-CAM composites, leaving a surface richer in the organic phase, which is known to have a lower hardness. For Vita Enamic, the organic matrix could have been removed from the polymer-infiltrated ceramic network, thus exposing the feldspathic network, and fragilizing the surface[4]. In the IPS e.max CAD material, abrasive particles may have attacked the glass matrix, which is less resistant than the stronger and harder crystals[34]. There is evidence that restorative materials with lower hardness are more prone to abrasive wear[23,30]. Thereby, the decrease in microhardness caused by whitening toothpastes on the CAD-CAM composite resins may directly increase their wear. Both microhardness and roughness tests are useful for evaluating the characteristics of composition in relation to wear potential and surface loss[1,7,17,34].

The study demonstrated that there were no significant differences in the percentage variation of roughness or microhardness between the materials brushed with the same toothpaste, indicating similar behavior across the different materials. Therefore, the results suggest that the observed changes are likely attributed to the composition of the toothpastes.

In the present study, all specimens were subjected to 100,000 brushing cycles, with one-cycle consisting of an individual forward and backward stroke. The correlation between clinical brushing duration and cycles on an automated machine has been reported to simulate between 4 and 10 years of clinical wear[6,16]. This study simulated a brushing duration of 2 to 3.5 years, considering an average daily toothbrushing duration between 65.2 and 83.5 seconds[8].

Limitations for the present in vitro study did not consider the effects of pH, saliva pellicle, and temperature changes that occur in the oral environment nor restorative material wear. Future studies should address the effect of sensitivity and whitening toothpastes on the wear, gloss, and elastic modulus of CAD-CAM composite resins. Also, the effect of these toothpastes on the clinical performance of these restorative materials is worthy of being investigated.

Within the limitations of this current study, it was concluded that sensitivity toothpastes resulted in higher surface roughness and lower hardness of indirect CAD-CAM resin composites when compared to regular and whitening toothpastes.

Acknowledgments

We would like to thank the prosthetic laboratories Calgaro and Stillo Arte Dental for their support with the crystallization and sintering process of ceramic materials. We also thank Rafael da Costa Machado and Monica Castillo for the English translation/revision of the manuscript.

Conflict of Interest

The authors have no conflict of interest to disclose.

Data availability

Datasets related to this article will be available to the corresponding author upon request.

Author Contribution

Gladys Juanita Teresa Purizaga Patiño: Study conception and design, acquisition of data or analysis, interpretation of data, article writing, review and final approval. **Elim Karine da Silva de Oliveira Sirino:** Acquisition of data or analysis, interpretation of data, article writing and review and final approval. **Aline Cristina Batista Rodrigues Johann:** Study conception and design, interpretation of data, review and final approval. **Luciana Reis Azevedo-Alanis:** Study conception and design, interpretation of data, review and final approval. **Evelise Machado de Souza:** Study conception and design, interpretation of data, review and final approval. **Rodrigo Nunes Rached:** Study conception and design, acquisition of data or analysis, interpretation of data, article writing, review and final approval. All authors actively revised and approved the final version of the manuscript.

References

1. João-Souza SH, Lussi A, Baumann T, Scaramucci T, Aranha ACC, Carvalho TS. Chemical and physical factors of desensitizing and/or anti-erosive toothpastes associated with lower erosive tooth wear. Sci Rep. 2017 Dec 20;7(1):17909. doi: 10.1038/s41598-017-18154-8.
2. Lopes RM, Turbino ML, Zezell DM, Scaramucci T, Aranha AC. The effect of desensitizing dentifrices on dentin wear and tubule occlusion. Am J Dent. 2015 Oct;28(5):297-302.
3. Butera A, Pascadopoli M, Gallo S, Lelli M, Tarterini F, Giglia F, et al. SEM/EDS evaluation of the mineral deposition on a polymeric composite resin of a toothpaste containing biomimetic Zn-Carbonate Hydroxyapatite (microRepair®) in oral environment: a randomized clinical trial. Polymers (Basel). 2021 Aug;13(16):2740. doi: 10.3390/polym13162740.
4. Nima G, Lugo-Varillas JG, Soto J, Faraoni JJ, Palma-Dibb RG, Correa-Medina A, et al. Effect of toothbrushing on the surface of enamel, direct and indirect CAD/CAM restorative materials. Int J Prosthodont. 2021 July/August;34(4):473-81. doi: 10.11607/ijp.6594.
5. Takahashi R, Jin J, Nikaido T, Tagami J, Hickel R, Kunzelmann KH. Surface characterization of current composites after toothbrush abrasion. Dent Mater J. 2013;32(1):75-82. doi: 10.4012/dmj.2012-160.
6. Kamonkhantikul K, Arksornnukit M, Takahashi H, Kanehira M, Finger WJ. Polishing and toothbrushing alters the surface roughness and gloss of composite resins. Dent Mater J. 2014;33(5):599-606. doi: 10.4012/dmj.2014-111.
7. Koizumi H, Saiki O, Nogawa H, Hiraba H, Okazaki T, Matsumura H. Surface roughness and gloss of current CAD/CAM resin composites before and after toothbrush abrasion. Dent Mater J. 2015;34(6):881-7. doi: 10.4012/dmj.2015-177.
8. Di Fiore A, Stellini E, Basilicata M, Bollero P, Monaco C. Effect of toothpaste on the surface roughness of the resin-contained CAD/CAM dental materials: a systematic review. J Clin Med. 2022 Jan;11(3):767. doi: 10.3390/jcm11030767.
9. Flury S, Peutzfeldt A, Lussi A. Influence of surface roughness on mechanical properties of two computer-aided design/computer-aided manufacturing (CAD/CAM) ceramic materials. Oper Dent. 2012 Nov-Dec;37(6):617-24. doi: 10.2341/11-391-L.
10. Stawarczyk B, Özcan M, Trottmann A, Schmutz F, Roos M, Hämmerle C. Two-body wear rate of CAD/CAM resin blocks and their enamel antagonists. J Prosthet Dent. 2013 May;109(5):325-32. doi: 10.1016/S0022-3913(13)60309-1.
11. Kamonkhantikul K, Arksornnukit M, Lauvahutanon S, Takahashi H. Toothbrushing alters the surface roughness and gloss of composite resin CAD/CAM blocks. Dent Mater J. 2016;35(2):225-32. doi: 10.4012/dmj.2015-228.
12. Aref NS, Abdallah RM. surface analysis and spectrophotometric evaluation of different esthetic restorative materials frequently exposed to a desensitizing agent. Int J Biomater. 2021 Apr;2021:9989747. doi: 10.1155/2021/9989747.

13. da Costa J, Adams-Belusko A, Riley K, Ferracane JL. The effect of various dentifrices on surface roughness and gloss of resin composites. J Dent. 2010;38 Suppl 2:e123-8. doi: 10.1016/j.jdent.2010.02.005.

14. Joiner A, Pickles MJ, Lynch S, Cox TF. The measurement of enamel wear by four toothpastes. Int Dent J. 2008 Feb;58(1):23-8. doi: 10.1111/j.1875-595x.2008.tb00173.x.

15. Franzò D, Philpotts CJ, Cox TF, Joiner A. The effect of toothpaste concentration on enamel and dentine wear in vitro. J Dent. 2010 Dec;38(12):974-9. doi: 10.1016/j.jdent.2010.08.010.

16. Augusto MG, Borges AB, Pucci CR, Mailart MC, Torres CRG. Effect of whitening toothpastes on wear and roughness of ormocer and methacrylate-based composites. Am J Dent. 2018 Dec;31(6):303-8.

17. Mosquim V, Martines Souza B, Foratori Junior GA, Wang L, Magalhães AC. The abrasive effect of commercial whitening toothpastes on eroded enamel. Am J Dent. 2017 Jun;30(3):142-6.

18. Macdonald E, North A, Maggio B, Sufı F, Mason S, Moore C, et al. Clinical study investigating abrasive effects of three toothpastes and water in an in situ model. J Dent. 2010 Jun;38(6):509-16. doi: 10.1016/j.jdent.2010.03.007.

19. Lima LC, Viana ÍEL, Paz SLPD, Bezerra SJC, João-Souza SH, Carvalho TS, Scaramucci T. Role of desensitizing/whitening dentifrices in enamel wear. J Dent. 2020 Aug;99:103390. doi: 10.1016/j.jdent.2020.103390.

20. Rostamzadeh P, Omrani LR, Abbasi M, Yekaninejad MS, Ahmadi E. Effect of whitening toothpastes containing activated charcoal, abrasive particles, or hydrogen peroxide on the color of aged microhybrid composite. Dent Res J (Isfahan). 2021 Dec 10;18:106.

21. Moore C, Addy M. Wear of dentine in vitro by toothpaste abrasives and detergents alone and combined. J Clin Periodontol. 2005 Dec;32(12):1242-6. doi: 10.1111/j.1600-051X.2005.00857.x.

22. Tellefsen G, Liljeborg A, Johannsen A, Johannsen G. The role of the toothbrush in the abrasion process. Int J Dent Hyg. 2011 Nov;9(4):284-90. doi: 10.1111/j.1601-5037.2011.00505.x.

23. Flury S, Diebold E, Peutzfeldt A, Lussi A. Effect of artificial toothbrushing and water storage on the surface roughness and micromechanical properties of tooth-colored CAD-CAM materials. J Prosthet Dent. 2017 Jun;117(6):767-74. doi: 10.1016/j.prosdent.2016.08.034. Epub 2016 Nov 14.

24. Turgut S, Kılınç H, Ulusoy KU, Bagis B. The effect of desensitizing toothpastes and coffee staining on the optical properties of natural teeth and microhybrid resin composites: an in-vitro study. Biomed Res Int. 2018 Dec;2018:9673562. doi: 10.1155/2018/9673562.

25. Aykent F, Yondem I, Ozyesil AG, Gunal SK, Avunduk MC, Ozkan S. Effect of different finishing techniques for restorative materials on surface roughness and bacterial adhesion. J Prosthet Dent. 2010 Apr;103(4):221-7. doi: 10.1016/S0022-3913(10)60034-0.

26. Bollen CM, Lambrechts P, Quirynen M. Comparison of surface roughness of oral hard materials to the threshold surface roughness for bacterial plaque retention: a review of the literature. Dent Mater. 1997 Jul;13(4):258-69. doi: 10.1016/s0109-5641(97)80038-3.

27. Dos Santos PH, Brogin FF, Catelan A, Suzuki TY, Guedes AP, Pavan S, et al. Effect of whitening and desensitizing dentifrices on composite surfaces treated with surface sealants. J Investig Clin Dent. 2013 May;4(2):101-6. doi: 10.1111/jicd.12004. Epub 2012 Oct 17.

28. Lauvahutanon S, Takahashi H, Shiozawa M, Iwasaki N, Asakawa Y, Oki M, et al. Mechanical properties of composite resin blocks for CAD/CAM. Dent Mater J. 2014;33(5):705-10. doi: 10.4012/dmj.2014-208.

29. Nguyen JF, Migonney V, Ruse ND, Sadoun M. Resin composite blocks via high-pressure high-temperature polymerization. Dent Mater. 2012 May;28(5):529-34. doi: 10.1016/j.dental.2011.12.003.

30. de Andrade GS, Augusto MG, Simões BV, Pagani C, Saavedra GSFA, Bresciani E. Impact of simulated toothbrushing on surface properties of chairside CAD-CAM materials: An in vitro study. J Prosthet Dent. 2021 Mar;125(3):469.e1-6. doi: 10.1016/j.prosdent.2020.08.028. Epub 2020 Dec 2.

31. Marchesi G, Camurri Piloni A, Nicolin V, Turco G, Di Lenarda R. Chairside CAD/CAM materials: current trends of clinical uses. biology (Basel). 2021 Nov;10(11):1170. doi: 10.3390/biology10111170.

32. Eldafrawy M, Greimers L, Bekaert S, Gailly P, Lenaerts C, Nguyen JF, et al. Silane influence on bonding to CAD-CAM composites: An interfacial fracture toughness study. Dent Mater. 2019 Sep;35(9):1279-90. doi: 10.1016/j.dental.2019.05.019.

33. Al-Harbi FA, Ayad NM, ArRejaie AS, Bahgat HA, Baba NZ. Effect of aging regimens on resin nanoceramic chairside CAD/CAM material. J Prosthodont. 2017 Jul;26(5):432-9. doi: 10.1111/jopr.12408. Epub 2015 Dec 14.

34. Ludovichetti FS, Trindade FZ, Werner A, Kleverlaan CJ, Fonseca RG. Wear resistance and abrasiveness of CAD-CAM monolithic materials. J Prosthet Dent. 2018 Aug;120(2):318.e1-8. doi: 10.1016/j.prosdent.2018.05.011.

35. Zhi L, Bortolotto T, Krejci I. Comparative in vitro wear resistance of CAD/CAM composite resin and ceramic materials. J Prosthet Dent. 2016 Feb;115(2):199-202. doi: 10.1016/j.prosdent.2015.07.011. Epub 2015 Oct 14.