THE JOURNAL OF PROSTHETIC DENTISTRY

RESEARCH AND EDUCATION

Effect of surface treatments on wear and surface properties of different CAD-CAM materials and their enamel antagonists

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ABSTRACT

Statement of problem. Which surface treatment provides optimal surface roughness, microhardness, and wear behavior for computer-aided design and computer-aided manufacturing (CAD-CAM) materials and their enamel antagonists is unclear.

Purpose. The purpose of this in vitro study was to evaluate the effect of surface treatment on the surface roughness, microhardness, and 2-body wear of different CAD-CAM materials and their enamel antagonists.

Material and methods. Monolithic zirconia, polymer-infiltrated ceramic network, lithium disilicate, leucite-reinforced ceramic, zirconia-reinforced lithium silicate, and feldspathic ceramic specimens were sliced into 2-mm-thick rectangular plates and divided into polished or glazed subgroups (n=6). After surface roughness and microhardness measurements, the specimens were loaded at 49 N for 250 000 cycles and simultaneously thermocycled (5 °C and 55 °C). All specimens were scanned before and after the wear test by using a scanner. The volumetric loss and wear depth of the materials and the volumetric and height loss of the enamel were calculated, and scanning electron microscope images of the specimens were made. Multiple 2-way ANOVAs and Tukey honestly significant difference tests were used to assess the effect of material and surface treatment on surface roughness, microhardness, and wear behavior of materials and enamel (α=.05).

Results. Material and surface treatment interactions affected the surface roughness (P<.001), microhardness (P<.001), volumetric loss of materials (P=.044), and height loss of enamel (P<.001).

Conclusions. Polishing resulted in higher surface roughness and microhardness than glazing. Volumetric loss depended on the material, which affected the height loss of the antagonists. Glazing and polishing had similar effects on the volumetric loss of materials and antagonists. No correlation was found between the wear of materials and the antagonists, nor between the surface roughness of materials and the volumetric loss of materials or antagonists. (J Prosthet Dent 2023;129:495-506)

A restorative material should have wear properties similar to those of enamel, have adequate wear resistance, and minimize the wear of the antagonist teeth.[1-27] Enamel wear has been reported to depend on the surface roughness, microhardness, frictional resistance, strength, texture, microstructural characteristics (porosity and grain size), and surface treatment (glazed or polished) of the antagonist.[3,5,10,12-14,26,28-34] An understanding of the wear mechanism and its controlling factors is critical for predicting long-term success.[3,35]

Computer-aided design and computer-aided manufacturing (CAD-CAM) materials are increasingly used because of their favorable properties,[2,36-38] and monolithic restorations have become popular.[38-42] The absence of a veneer material may reduce the wear of the material and that of the antagonist.[3,30,43] Additionally, the ceramic type may affect wear.[3,43-47]

Presented at Turkish Dental Association (TDB) 24th International Dental Congress. 28 September, Ankara, Turkey, as oral presentation (In vitro wear resistance and surface properties of CAD-CAM materials).
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Clinical Implications

For the CAD-CAM materials tested, either glazing or polishing may be applied in terms of wear. Increased material wear may be expected when polymer-infiltrated ceramic network material is used compared with the other tested materials.

Although manufacturers have recommended both glazing and polishing for CAD-CAM restorations, whether glazing or polishing provides more favorable surface roughness and wear is still uncertain.[31-34] Ludovichetti et al[40] reported that microhardness should also be considered for predicting wear when selecting a material. Therefore, measuring the surface roughness and microhardness of CAD-CAM materials may be beneficial to understand the wear behavior of new materials and their enamel antagonists. The purpose of this in vitro study was to investigate the effect of different surface treatments (glazed or polished) on the surface roughness, microhardness, and 2-body wear behavior of different CAD-CAM materials and human enamel antagonists. The null hypotheses were that material and surface treatment (glazed or polished) would not affect the surface roughness and microhardness, that material and surface treatment would not affect 2-body wear behavior (volumetric loss and wear depth) of materials, that material and surface treatment would not affect 2-body wear behavior (volumetric loss and height loss) of antagonists, that no correlation would be found between 2-body wear behavior of materials and antagonists, and that no correlation would be found between surface roughness of materials and volumetric loss of materials or antagonists.

MATERIAL AND METHODS

Six types of monolithic CAD-CAM materials (zirconia [Zir], lithium disilicate glass-ceramic [LDS], leucite glass-ceramic [LC], zirconia-reinforced lithium silicate glass-ceramic [ZLS], feldspathic glass-ceramic [FP], and polymer-infiltrated ceramic network [PICN]) (n=12) (Table 1) were wet-sectioned (Vari/cut VC-50; Leco Corp) to obtain 2-mm-thick rectangular plates. The Zir specimens were cut 20% thicker and sintered (Programat S1 1600; Ivoclar AG).[38] The ZLS and LDS specimens were crystallized (Programat EP5000; Ivoclar AG).[39] Sintering and crystallization were performed according to the manufacturers' recommendations. The specimens were polished with 600-grit silicon carbide abrasive paper (Leco; Leco Corp) under running water and divided into 2 subgroups according to the surface treatments (glazed or polished) (n=6). The sample size of 6 per material was selected based on previous studies.[48,49] All surface treatments were performed on 1 side of the specimens by 1 clinician (G.Ç.).

Table 1. Materials used

Material	Classification	Code	Manufacturer	Lot Number
LAVA Plus Zirconia	3-mol% yttria partially stabilized zirconia polycrystalline ceramic (3Y-PSZ)	Zir	3M ESPE	547433
IPS e.max CAD	Lithium disilicate glass-ceramic	LDS	Ivoclar AG	U22012
IPS Empress CAD	Leucite glass-ceramic	LC	Ivoclar AG	U22653
VITA Suprinity PC	Zirconia-reinforced lithium silicate glass-ceramic	ZLS	VITA Zahnfabrik	36851
CEREC Blocks C	Feldspathic glass-ceramic	FP	Dentsply Sirona	42461
VITA ENAMIC	Polymer-infiltrated ceramic network	PICN	VITA Zahnfabrik	45810

In the glazed groups (n=6), a thin layer of glaze was sprayed (except PICN) from the same distance, and a dry and uniform whitish glaze layer was achieved on all specimens. Glaze firings were performed for Zir, ZLS, and FP (VITA AKZENT Plus Glaze LT Spray; VITA Zahnfabrik) specimens at 800 °C for 60 seconds and for LC and LDS (IPS e.max CAD Crystall./Glaze Spray; Ivoclar AG) specimens at 770 °C for 90 seconds.[38,39] For PICN specimens, a 5% hydrofluoric acid gel (VITA Ceramics Etch; VITA Zahnfabrik) was applied for 60 seconds, rinsed, and air-dried. A silane coupling agent (VITA ADIVA C-PRIME; VITA Zahnfabrik) was applied for 60 seconds and air-dried. Then, a thin layer of glaze material (VITA ENAMIC GLAZE; VITA Zahnfabrik) was applied and light polymerized for 60 seconds (Bluephase C8; Ivoclar AG). To ensure the adequate glaze thickness (200 ±12 μm), the ceramic thickness was measured by using digital calipers (Model number NB60; Mitutoyo) before and after glaze applications.[50]

In the polished groups (n=6), the specimens were manually polished by using a low-speed handpiece, diamond polishing paste (OptraFine HP Polishing Paste; Ivoclar AG),[39] and the manufacturer's polishing systems: VITA ENAMIC Polishing Set Technical for PICN, VITA SUPRINITY Polishing Set Technical for Zir, FP, and ZLS; VITA Zahnfabrik (both 2-step systems) and OptraFine Assortment for LC and LDS; Ivoclar AG (a 3-step system).

Two notches were made on 1 surface of all specimens by using a diamond rotary instrument (Round diamond bur 801-314-018-C; Coltène Dental) to facilitate the scanning. Additionally, corners of the specimens were cut to obtain an octagon shape to facilitate the superimpositions. Custom-made molds were fabricated for the lower part of the mastication simulator. The CAD-CAM specimens were ultrasonically cleaned for 10 minutes

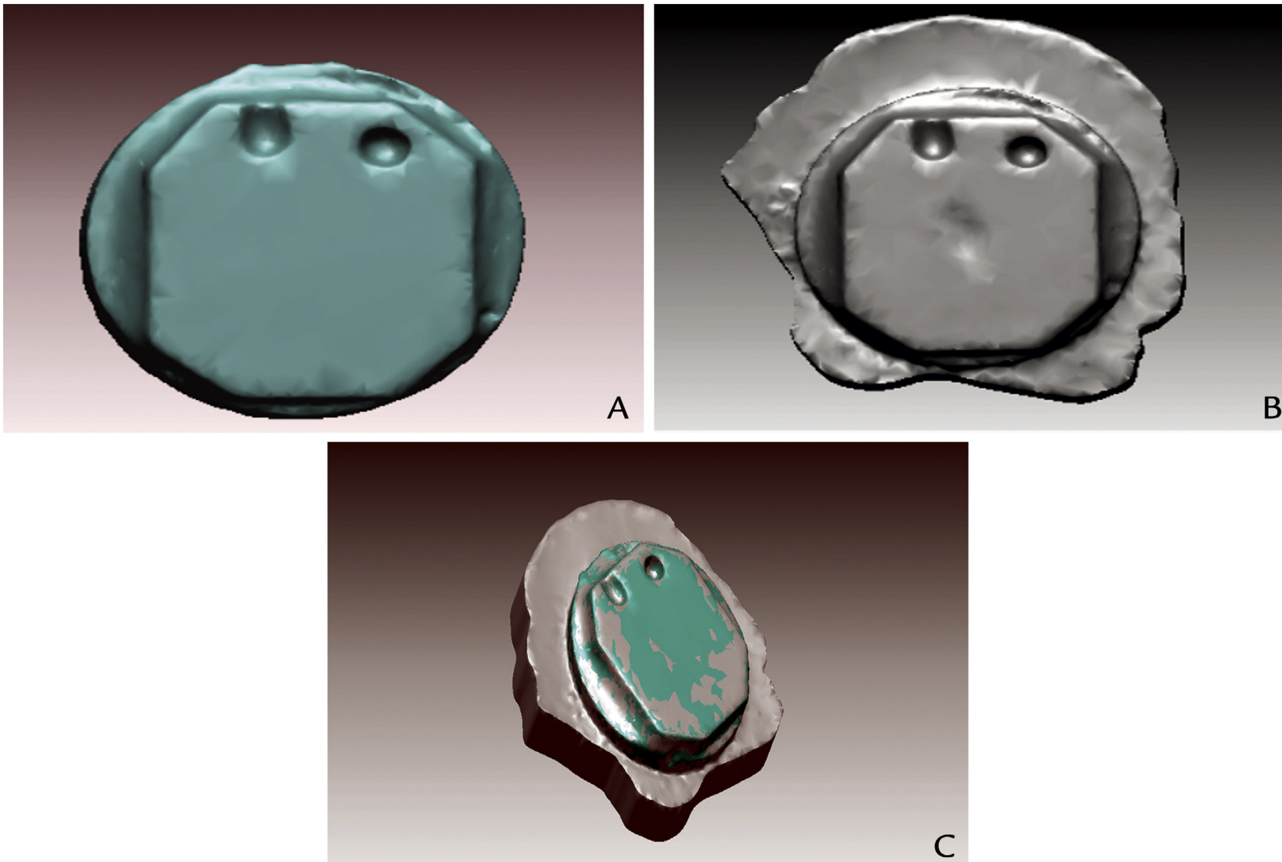

Figure 1. Representative images of CAD-CAM materials before and after mastication simulation and superimposition. A, Before; B, After; C, Superimposition. CAD-CAM, computer-aided design and computer-aided manufacturing.

(Jelsonic; Jelenko), embedded in molds with an autopolymerizing acrylic resin (Meliodent; Kulzer GmbH), and stored in distilled water at 37 °C for 24 hours.[51]

The surface roughness (R_a) of each specimen was measured 2 times (5.5-mm tracing length, 0.8-mm cutoff length, and 1-mm/s stylus speed) by using a contact profilometer (Perthometer M2; Mahr GmbH) before the wear test. The mean R_a values (μm) were calculated.[52]

For enamel antagonists, caries-free maxillary human first molars were collected (Istanbul Aydın University Clinical Research Local Ethic Committee (480.2/065), cleaned, and stored in 0.05% thymol and distilled water.[53] Teeth with intact cusps were included, and the mesiobuccal cusps were wet-sectioned by using a low-speed handpiece. Pentagon-shaped metal screw holders were designed for the upper part of the mastication simulator. Then, the mesiobuccal cusps were fixed in the middle of the screw holders with the same autopolymerizing acrylic resin, leaving 2 mm of the cusps exposed (N=72).[48,49] The tips of the mesiobuccal cusps were then adjusted to a spherical shape[48,49,53] and wet ground with 2400-grit silicon carbide paper (Leco; Leco Corp). Enamel antagonists were divided into 6 subgroups (per material, n=12).

A dual-axis computer-controlled mastication simulator (Chewing Simulator; Esetron Smart Robotechnologies) was used for wear simulation. Enamel antagonists and specimens were fixed to the holders of the mastication simulator. A vertical load of 49 N was applied with 1.67 Hz frequency, a lateral movement of 0.7 mm, and a vertical and lateral sliding speed of 60 mm/s for 250 000 cycles.[2] The contact time of enamel antagonist-ceramic during the sliding motion was 120 ms, and the total contact time was 330 ms. The specimens were simultaneously thermocycled (1000 cycles, 60-second holding time, 15-second transfer time, and 5 °C and 55 °C).[54-56]

The CAD-CAM specimens and enamel antagonists were scanned before (baseline) and after the wear test (follow-up)[2,53] by using an intraoral scanner (CEREC Omnicam 4.4.1; Dentsply Sirona) to obtain standard tessellation language (STL) files (Figs. 1, 2). Baseline and follow-up scans of the same specimen were superimposed by using a software program (VRMesh Studio; VirtualGrid).[53,57] For superimpositions, unaltered reference areas, pentagon edges of metal screw holders, octagon edges of specimens, and notches were used to minimize errors. Color-mapped models of each specimen

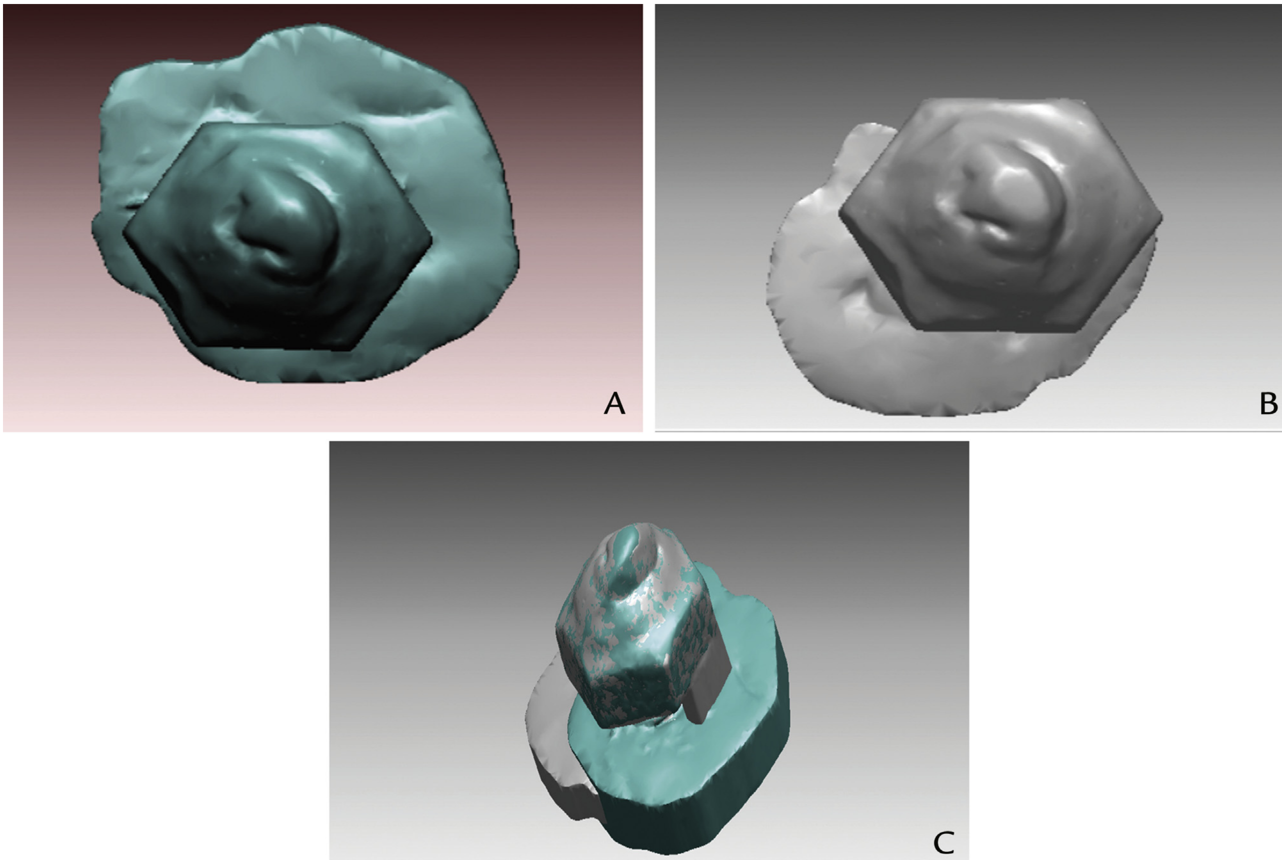

Figure 2. Representative images of enamel antagonists before and after mastication simulation and superimposition. A, Before; B, After; C, Superimposition.

were created by using the software program to detect the geometric changes, linear reduction, and volumetric loss that illustrate the wear.[53] Volumetric loss (mm^3) and the wear depth (mm) of each superimposed specimen and the volumetric loss (mm^3) and height loss (mm) of their antagonists were calculated.[2,48,53,58] For the qualitative analysis of worn surfaces, 1 specimen from each group was evaluated by using a scanning electron microscope (SEM) (LEO 440; Zeiss) at ×700 magnification after the wear tests.[48,49]

Five additional specimens from each surface treatment group were fabricated for the microhardness test and stored in distilled water at 37 °C for 24 hours.[58] The specimens were placed in a Vickers microhardness tester (HMV; Shimadzu Corp), and 2 indentations were made for each specimen (9.8-N load, 15-second dwell time).[58] The major diameters of the Vickers indentations (d1 and d2) were measured, and Vickers hardness values were calculated: Hardness =1850×Load/(d1×d2).[58]

Six 2-way analyses of variance (ANOVAs) were performed for the surface roughness, microhardness, volumetric loss, and wear depth of materials, and the volumetric loss and height loss of the enamel antagonists were measured by using a statistical software program (IBM SPSS Statistics, v25.0; IBM Corp). Surface treatment and material were the main effects with the interaction included. The Tukey honestly significant difference post hoc comparisons were used for any significant interactions. Pairwise correlations of surface roughness-volumetric loss of materials, surface roughness-volumetric loss of antagonists, antagonists' volumetric loss-materials' volumetric loss, and antagonists' height loss-materials' wear depth were analyzed by using the Spearman correlation analysis (α=.05).

RESULTS

According to the 2-way ANOVA (Table 2), material (P<.001), surface treatment (P<.001), and material and surface treatment interactions (P<.001) affected the surface roughness and microhardness. The polished groups had higher surface roughness ($P\leq$.026) than the glazed groups except PICN (P=1.00) and LDS (P=.052) (Table 3). Polished LC ($P\leq$.016) had the highest surface roughness. Only polished Zir (P<.001) and PICN (P<.001) had higher microhardness than their glazed groups. Glazed

Table 2. Summary of ANOVA of surface roughness, microhardness, CAD-CAM materials' volumetric loss and wear depth and antagonist enamels' volumetric loss and height loss

Test	Effect	df	F	P
Surface roughness	Material type	5	10.78	<.001
	Surface treatment type	1	139.65	<.001
	Material× surface treatment	5	12.37	<.001
Microhardness	Material type	5	330.58	<.001
	Surface treatment type	1	217.4	<.001
	Material× surface treatment	5	71.95	<.001
Volumetric loss of CAD-CAM materials	Material type	5	10.4	<.001
	Surface treatment type	1	0.318	.575
	Material× surface treatment	5	2.45	.044
Wear depth of CAD-CAM materials	Material type	5	1.27	.289
	Surface treatment type	1	0.698	.407
	Material× surface treatment	5	0.806	.55
Volumetric loss of antagonist enamel	Material type	5	0.892	.492
	Surface treatment type	1	1.81	.184
	Material× surface treatment	5	0.710	.618
Height loss of antagonist enamel	Material type	5	3.844	.004
	Surface treatment type	1	1.698	.198
	Material× surface treatment	5	5.633	<.001

CAD-CAM, computer-aided design and computer-aided manufacturing; df, numerator degrees of freedom.

PICN had the lowest microhardness (*P*<.001), whereas polished Zir had the highest microhardness (*P*<.001) (Table 3).

According to the 2-way ANOVA, material (*P*<.001, *P*=.004) and material and surface treatment interactions (*P*=.044, *P*<.001) affected the volumetric loss of materials and height loss of antagonists. Material type (*P*=.289, *P*=.492) and surface treatment type (*P*=.407, *P*=.184) had no effect on the wear depth of materials and volumetric loss of antagonists. Glazed PICN had higher volumetric loss than the glazed and polished groups of other materials (*P*≤.024) (Table 4, Fig. 3A). Glazed Zir (*P*=.044) and LC (*P*=.028) had lower volumetric loss than the polished PICN. In terms of volumetric loss (*P*≥.538) and wear depth (*P*≥.855) and the height loss (*P*≥.155) and volumetric loss (*P*≥.993) of their antagonists, there was no difference between the glazed and polished groups of the materials (Figs. 3, 4). The mean height loss of antagonists was higher in the polished FP (*P*≤.039, *P*=.005) and glazed ZLS (*P*≤.048, *P*=.006) than in the PICN (glazed and polished groups) and the glazed Zir groups. Additionally, the glazed Zir led to less height loss of antagonists than the polished LC (*P*=.016) and the glazed LDS (*P*=.012).

According to the Spearman correlation analysis, there was no significant correlation between the surface roughness of materials and volumetric loss of materials

Table 3. Mean ±standard deviation (SD) of surface roughness (Ra-µm) and microhardness of glazed and polished CAD-CAM materials

Material	Surface Treatment	Surface Roughness, Mean ±SD	Microhardness, Mean ±SD
Zir	Glazed	0.15 ±0.06[a]	648.50 ±20.75[cd]
	Polished	1.12 ±0.48[c]	1314.20 ±88.77[f]
LC	Glazed	0.18 ±0.09[a]	642.40 ±44.62[cd]
	Polished	1.65 ±0.30[d]	652.0 ±56.03[cd]
LDS	Glazed	0.19 ±0.06[ab]	562.50 ±14.50[c]
	Polished	0.66 ±0.54[bc]	608.5 ±35.27[cd]
PICN	Glazed	0.24 ±0.1[ab]	76.85 ±34.59[a]
	Polished	0.26 ±0.08[ab]	254.90 ±7.26[b]
ZLS	Glazed	0.33 ±0.12[ab]	683.10 ±57.75[de]
	Polished	0.95 ±0.17[c]	764.40 ±61.49[e]
FP	Glazed	0.43 ±0.05[ab]	565.70 ±29.42[c]
	Polished	0.94 ±0.15[c]	635.90 ±35.66[cd]

Different uppercase letters in the same column show significant differences (*P*<.05). Abbreviations as shown in Table 1. CAD-CAM, computer-aided design and computer-aided manufacturing.

Table 4. Mean ±standard deviation (SD) of volumetric loss (mm^3) and wear depth (mm) of CAD-CAM materials, and volumetric loss (mm^3) and height loss (mm) of enamel antagonists

Material	Surface Treatment	Volumetric Loss of CAD-CAM Materials	Wear Depth of CAD-CAM Materials	Volumetric Loss of Enamel Antagonists	Height Loss of Enamel Antagonists
Zir	Glazed	1.31 ±0.61[a]	0.03 ±0.02[e]	3.29 ±3.22[d]	0.08 ±0.07[a]
	Polished	1.39 ±1.14[ab]	0.05 ±0.02[e]	2.03 ±2.24[d]	0.26 ±0.06[abc]
LC	Glazed	1.19 ±1.28[a]	0.04 ±0.05[e]	3.32 ±3.18[d]	0.20 ±0.1[abc]
	Polished	2.84 ±1.32[ab]	0.03 ±0.03[e]	2.03 ±2.69[d]	0.35 ±0.28[bc]
LDS	Glazed	1.78 ±1.31[ab]	0.03 ±0.02[e]	2.15 ±1.95[d]	0.36 ±0.13[bc]
	Polished	2.19 ±1.00[ab]	0.06 ±0.04[e]	1.35 ±0.75[d]	0.22 ±0.05[abc]
PICN	Glazed	5.64 ±1.16[c]	0.02 ±0.02[e]	1.53 ±1.05[d]	0.12 ±0.07[ab]
	Polished	3.94 ±1.58[bc]	0.01 ±0.02[e]	0.91 ±0.80[d]	0.13 ±0.04[ab]
ZLS	Glazed	1.98 ±1.36[ab]	0.03 ±0.03[e]	1.64 ±1.53[d]	0.37 ±0.15[c]
	Polished	1.69 ±1.39[ab]	0.04 ±0.03[e]	2.95 ±1.53[d]	0.19 ±0.1[abc]
FP	Glazed	2.63 ±2.02[ab]	0.04 ±0.03[e]	2.71 ±2.57[d]	0.17 ±0.08[abc]
	Polished	1.43 ±1.25[ab]	0.04 ±0.04[e]	1.44 ±0.97[d]	0.38 ±0.14[c]

Different uppercase letters in the same column show significant differences (*P*<.05). Abbreviations as shown in Table 1. CAD-CAM, computer-aided design and computer-aided manufacturing.

(*P*=.793) and antagonists (*P*=.656). In addition, there was no correlation between the 2-body wear behavior of the materials and their antagonists (*P*≥.146).

The SEM images (Figs. 5, 6) showed deeper furrows and scratches in the glazed groups, which were surrounded with some smooth insular areas. Except for Zir, LDS, and ZLS materials, the polished groups had surfaces with diffuse surface irregularities.

DISCUSSION

Material and surface treatment affected the surface roughness and microhardness; therefore, the first null hypothesis was rejected. The effect of material and surface treatment was significant (*P*<.001), and the material and

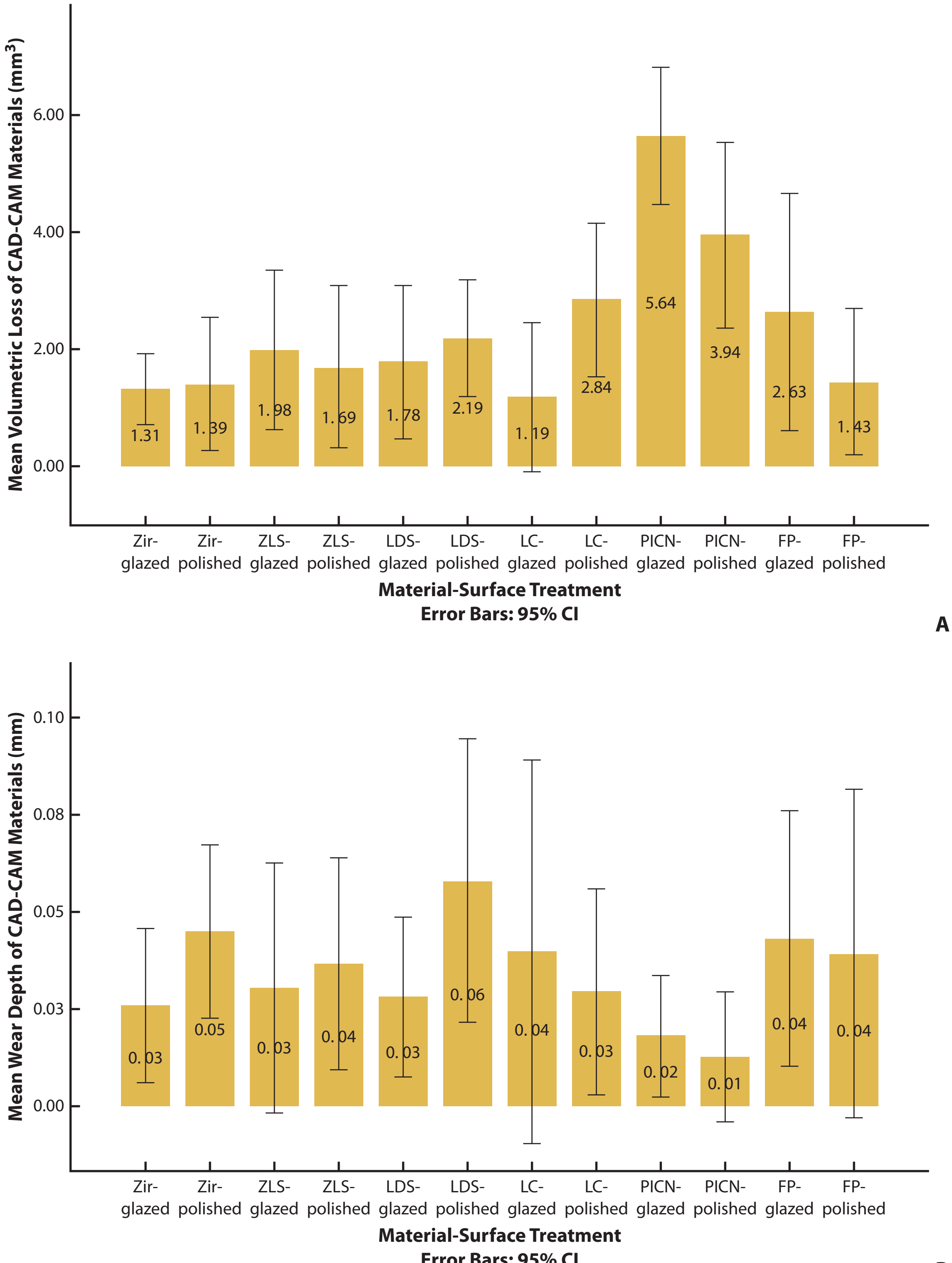

Figure 3. Mean and 95% confidence limits of different surface treatment groups of CAD-CAM materials. A, Volumetric loss (mm^3). B, Wear depth (mm). Abbreviations as shown in Table 1. CAD-CAM, computer-aided design and computer-aided manufacturing; SD, standard deviation.

surface treatment interaction affected the volumetric loss of materials. Therefore, the second null hypothesis was rejected. The third null hypothesis was rejected as the material affected the height loss of antagonists. No correlation was found between the wear behavior of the materials and their antagonists, and the fourth null hypothesis

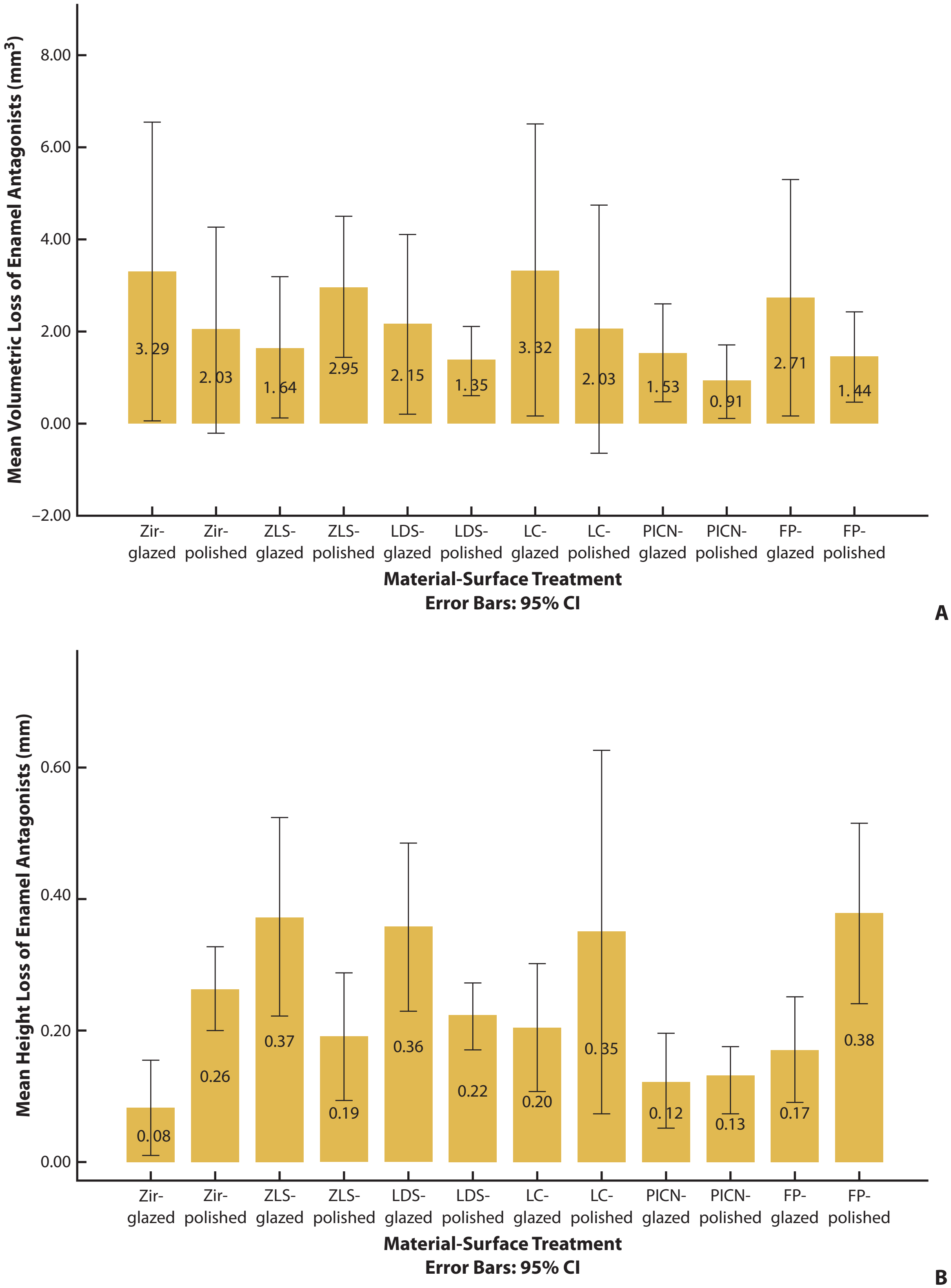

Figure 4. Mean and 95% confidence limits of enamel antagonists against different surface treatment groups of CAD-CAM materials. A, Volumetric loss (mm^3). B, Wear depth (mm). Abbreviations as shown in Table 1. CAD-CAM, computer-aided design and computer-aided manufacturing; SD, standard deviation.

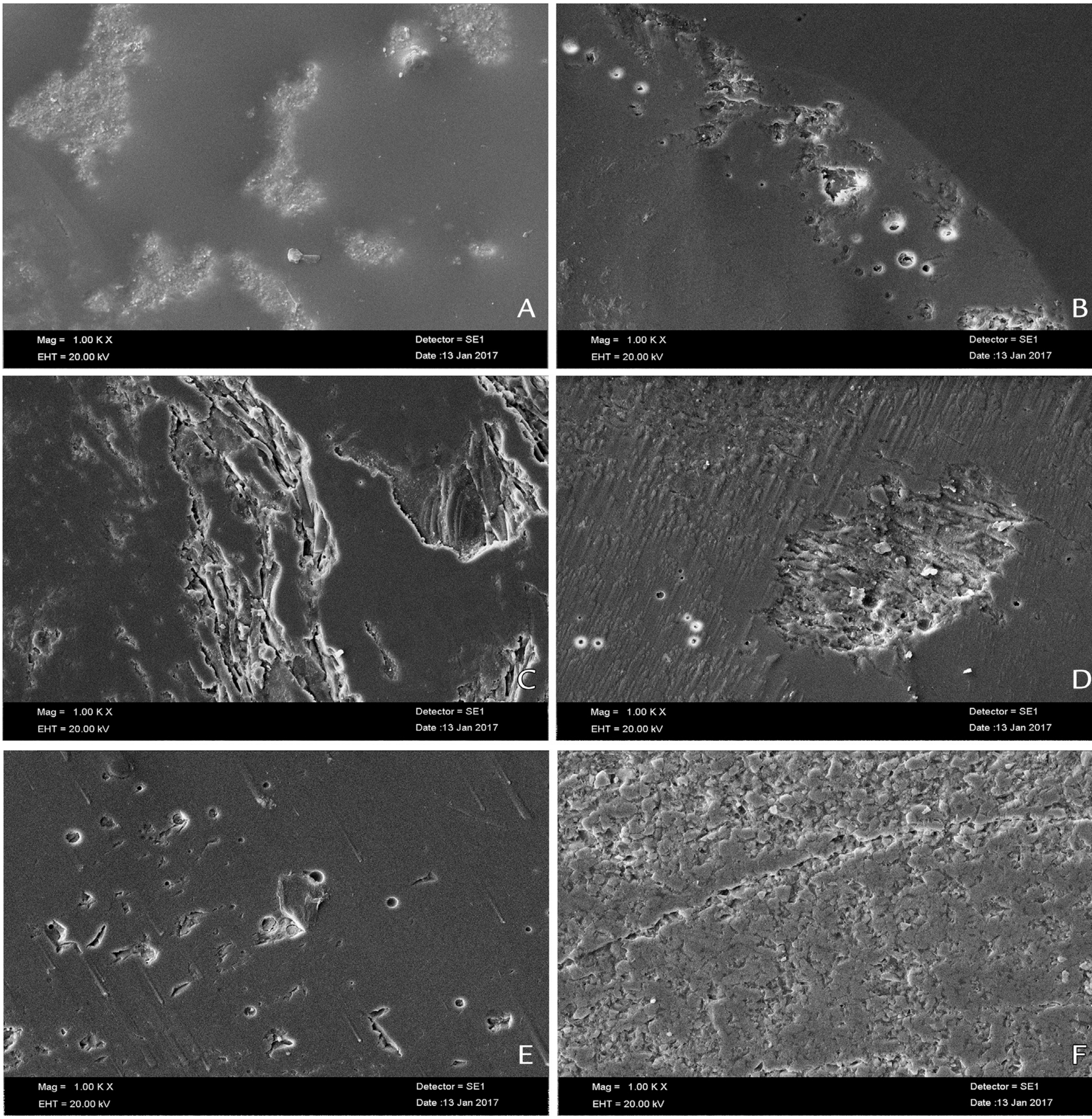

Figure 5. Scanning electron micrographs of glazed CAD-CAM material surfaces (original magnification ×1000). A, Zirconia; B, Lithium disilicate glass-ceramic; C, Leucite glass-ceramic; D, Zirconia-reinforced lithium silicate glass-ceramic; E, Feldspathic glass-ceramic; F, Polymer-infiltrated ceramic network material. CAD-CAM, computer-aided design and computer-aided manufacturing.

was accepted. The fifth null hypothesis was accepted because no correlation was found between the surface roughness and volumetric loss of the materials and antagonists.

All materials, except for PICN and LDS, had higher surface roughness in their polished groups. The surface roughness of ceramics has been reported to vary according to the surface treatment.[44] In SEM images after the wear test, the glazed groups had deeper furrows and scratches than the polished groups. Polished Zir, LDS, and ZLS had smoother surfaces, and polished groups of other materials had widespread surface irregularities with minimal scratches. Even though the polished groups had higher surface roughness before the wear test, glazing or polishing had no effect on the wear of the material or its antagonist. This might also explain the nonsignificant correlation between the initial surface roughness of materials and the wear of materials and their antagonists.

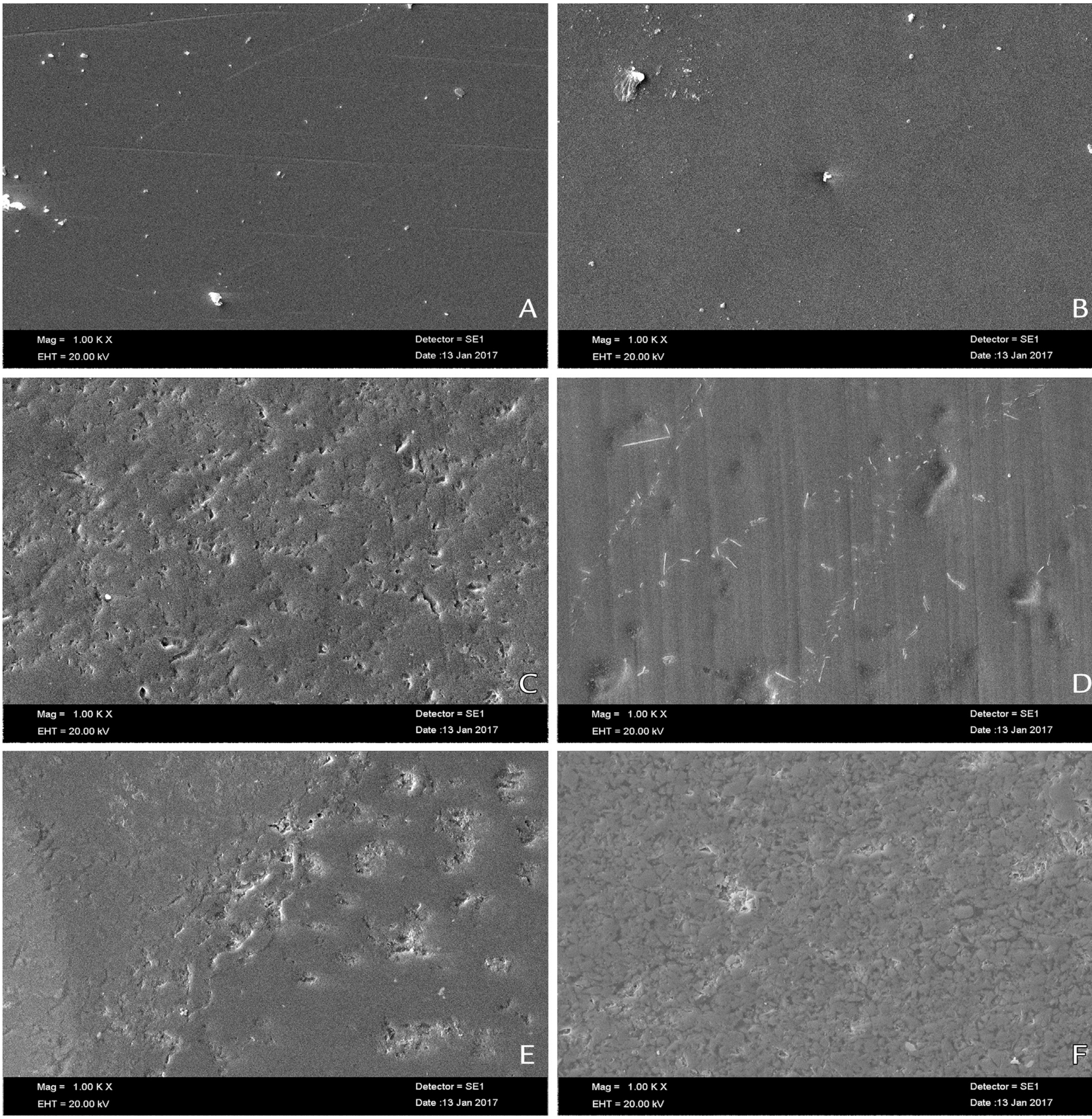

Figure 6. Scanning electron micrographs of polished CAD-CAM material surfaces (original magnification ×1000). A, Zirconia; B, Lithium disilicate glass-ceramic; C, Leucite glass-ceramic; D, Zirconia-reinforced lithium silicate glass-ceramic; E, Feldspathic glass-ceramic; F, Polymer-infiltrated ceramic network material.

Consistent with the results of the present study, no correlation was found between the surface roughness and the enamel antagonist wear[8,14,15] and the surface roughness and wear behavior of CAD-CAM materials,[9,40] attributed to the self-limiting effects of the rougher surfaces on the enamel antagonist wear over time,[16] changes in the surface roughness of ceramics,[27,31,40] decreases in the surface roughness of the enamel antagonists during the wear test,[17] polishing effects of ceramics on enamel surfaces,[18] absence of worn particles between the ceramics and antagonists,[12] and level of subsurface microcracks and chipping and pitting of enamel prisms depending on the enamel characteristics.[18-20]

In the present study, the tested enamel specimens were obtained from different patients and may have different characteristics. Therefore, tested ceramics may have different polishing and chipping effects on antagonists depending on the enamel characteristics and ceramic type. This might have changed the friction and diminished the wear differences obtained with different surface treatments. Additionally, as seen in the SEM images, the superficial glaze layer appeared to have worn with the antagonist cusp contact, while the polished groups maintained their surface properties. Worn glaze was reported to change surface roughness depending on the material's surface before glazing[8,49] and to affect the enamel and material wear.[44] Also, the structure of the underlying ceramic has been reported to affect the wear.[10] Therefore, wear of the glaze layer and exposed material structure, which was the same (glazed and polished groups), might have diminished the wear differences among groups. To further clarify the effects of surface roughness of ceramics and antagonists on wear, surface roughness measurements and SEM images are required of the antagonists and ceramics before, during, and after wear testing. The present study results suggest that glazing or polishing can be used for tested materials because they showed similar material and antagonist wear.

Conflicting results have been reported on the effect of microhardness on the enamel antagonist wear.[1,21,22,29,54] Defining a correlation between the microhardness and the wear of ceramics has been difficult because wear occurs as subsurface fractures.[1,29] Although Ludovichetti et al[40] did not apply any surface treatments, the reported order of the microhardness values were Zir>ZLS>LDS>PICN. In the present study, Zir (polished and glazed), LDS (glazed), and PICN (glazed) had lower hardness, whereas polished ZLS, LDS, PICN, and glazed ZLS had higher hardness than their results.[40] Hardness of polished Zir, LDS, and FP ceramics in the present study was similar to that of polished groups in the study by Hayashi et al,[54] and glazed Zir's hardness was similar to that of glazed Zir in the study by Campos et al. [59] Considering all findings, the effect of hardness on enamel wear is not clear and may depend on the composition of the material.

PICN had high volumetric loss, and its enamel antagonists had small height loss, which may be attributed to PICN's low microhardness.[11] Wear differences between PICN and other materials may be because of the difference in their microstructure and composition because PICN has 2 interconnected networks (86 wt% polymer and ceramic), whereas the other tested CAD-CAM materials do not have polymer networks.[58] PICN material wore more but can be considered antagonist-friendly. Similarly, Zhi et al[51] reported that PICN had higher wear than feldspathic CAD-CAM ceramic (Vita Mark II), and Ludovichetti et al[40] reported that PICN was more antagonist enamel-friendly than the glass-ceramics (ZLS and LDS) and Zir.

In previous studies, monolithic Zir was reported as wear-friendly with low antagonist wear,[12,13,23,44,53] attributed to its high microhardness.[11,12,32] In the present study, glazed Zir had lower volumetric loss than the PICN and was not significantly different from the other materials in terms of the volumetric loss, wear depth, and volumetric loss of enamel antagonists. Glazed Zir caused lower height loss on enamel antagonists than the polished LC and FP and the glazed LDS and ZLS. The material and enamel antagonist wear were similar when the Zir was polished or glazed. Previous studies[12,24,25,49] reported that polished Zir resulted in lower enamel antagonist wear than the glazed Zir and that the difference in results among studies may be because of the different mastication cycles applied, the tested zirconia, and the glaze. Consistent with previous studies,[12,13,44,53] the glazed and polished Zir tested in the present study may be considered wear-friendly.

The glass-ceramics (LDS, LC, ZLS, and FP) tested in the present study had similar wear. ZLS and LDS were also reported to have similar wear in previous studies.[26,40] Consistent with the present study, D'Arcangelo et al[2] reported that the wear depth and volumetric loss of glazed ZLS and other tested glass-ceramics (Imagine PressX, IPS e.max Press, IPS e.max CAD, and Vitablocs Mark II) were similar to each other and to human enamel. Contrarily, Matzinger et al[27] reported that the lowest depth was found in IPS e.max CAD, followed by ZLS, PICN, and resin composites, and the highest antagonist wear (ceramic antagonist) was found in LDS. Differences in results may be due to the different wear test methods and the material type.

Thermocycling was done simultaneously by using distilled water as a lubricant.[5,56] Different results may be obtained when different mediums are used. Limitations of the present study included that only the most commonly used surface treatments were tested. In future studies, different surface treatments such as polished + glazed, adjusted + glazed, or polished should be evaluated to simulate different clinical conditions. In the present study, enamel surfaces were modified for standardization.[48,49,53] However, modifying the enamel surfaces may change the enamel characteristics and affect wear. In future studies, the effects of modifying the enamel surfaces on the amount of enamel wear should be evaluated. Different loading cycles, occlusal forces, dysfunctional occlusion, the masticatory habits of patients, and diet can affect wear.[9,26,53] The findings of the present study should be corroborated with clinical studies.

CONCLUSIONS

Based on the findings of this in vitro study, the following conclusions were drawn:

1. Surface treatment and material affected the surface roughness and microhardness of materials, and

polishing resulted in higher surface roughness and microhardness than glazing.

2. The volumetric loss of CAD-CAM materials and the height loss of the enamel antagonist were affected by the material. However, the material was not found to affect the volumetric loss of antagonists or the wear depth of materials.
3. The PICN material had higher volumetric loss than the other CAD-CAM materials tested.
4. Surface treatment (glazed or polished) had no effect on the volumetric loss of materials or enamel antagonists.
5. No correlation was found between the wear behavior of materials and the enamel antagonists or the surface roughness of materials and the volumetric loss of materials or antagonists.

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Acknowledgments
The authors thank 3M ESPE and VITA Zahnfabrik for supplying the materials used in this study. The authors also thank Esetron Smart Robotechnologies for wear test, Semdent for providing the intraoral scanner, Erman Toktay for the statistical analysis, Ay Tasarım Ltd. for 2-body wear analysis, and Erciyes University Technology Research and Application Center for SEM analysis.

CRediT authorship contribution statement
Gülce Çakmak: Conceptualization, Data curation, Software, Writing - original draft. **Meryem Gülce Subaşı:** Conceptualization, Methodology, Investigation. **Murat Sert:** Investigation, Data curation, Project administration. **Burak Yilmaz:** Conceptualization, Supervision, Writing - review & editing.

https://doi.org/10.1016/j.prosdent.2021.06.023