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Effect of polishing versus glazing of CAD-CAM ceramics on wear and surface roughness of opposing composite resin

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ABSTRACT

Background: This study aimed to assess the effect of polishing versus glazing of computer-aided design-computer-aided manufacturing (CAD-CAM) ceramics on depth of wear and surface roughness of opposing composite resin.

Materials and Methods: This *in vitro* study was conducted on 40 Z250 composite and 40 CAD-CAM ceramic specimens including Celtra Duo, Vita Mark II, e.max CAD, and Vita Suprinity ceramics. All ceramic specimens were roughened by a fine-grit bur after primary glazing to simulate an adjusted surface in the clinical setting. They were then randomly assigned to two subgroups and underwent reglazing or polishing. All composite and ceramic specimens underwent profilometry after surface treatment and prior to the wear test, and the results were recorded quantitatively. Composite specimens were then subjected to 120,000 wear cycles against ceramic specimens in a chewing simulator, and the depth of wear was measured by a scanner. Data were statistically analyzed by repeated measures two-way analysis of variance (ANOVA) and one-way ANOVA (α = 0.05).

Results: Comparison of the surface roughness of composite specimens before and after the wear test revealed significant differences in both glazed Suprinity (P = 0.048) and Vita Mark II (P = 0.026) ceramics groups. The change in surface roughness after the wear test (compared with baseline) was significant in glazed (P = 0.000) and polished (P = 0.013) Vita Mark II and polished Suprinity (P = 0.037) ceramics, but this change was not significant in other ceramics (P > 0.05). The depth of wear after the wear test was not significantly different among the ceramic and composite subgroups (P > 0.05).

Conclusion: Assessment of depth of wear and surface roughness of composite specimens showed that the polishing kits of CAD-CAM ceramics can serve as a suitable alternative to reglazing.

Key Words: Composite resins, computer-aided design, dental restoration wear

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INTRODUCTION

Application of ceramics for the fabrication of dental restorations has greatly increased. Ceramic restorations can be fabricated by the laboratory or machining techniques such as computer-aided design-computer-aided manufacturing (CAD-CAM) systems.[1] The industrially fabricated CAD-CAM blocks have high structural homogeneity and fewer internal defects.[2] Rapid fabrication of highly accurate indirect ceramic restorations from readymade ceramic blocks is the main advantage of the CAD-CAM technique.[3]

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Despite the high precision of intraoral scanners and CAD-CAM milling machines, the final restoration cemented in the oral cavity may require further adjustments, necessitating a subsequent final finishing. However, finishing often leaves a rough surface, which enhances plaque accumulation and staining and causes increased wear of the opposing teeth and restorations.[4] Several approaches have been proposed to create a final smooth surface after finishing. Unlike the previous recommendations of the manufacturing companies regarding reglazing after intraoral adjustment of ceramic restorations, some manufacturers claim that the new dental ceramic finishing and polishing systems can create a smooth surface comparable to glazed ceramic.[5]

Composite resin restorations are conservative and cost-effective while tooth preparation for a full-crown restoration is highly invasive and can even result in pulpal involvement.[6-8] However, composite resins are susceptible to wear and surface roughening.[9-12] A worn and roughened composite surface enhances subsequent staining and bacterial adhesion.[13,14] Even the newly introduced composite resins with different monomers and novel filler technology are at risk of wear, and their wear behavior cannot be predicted by studies on similar products.[15]

Wear may occur due to direct contact of tooth and restorative material or contact of two opposing restorations in the process of mastication.[16] Wear is an unfavorable event that not only increases the surface roughness but may also lead to gradual loss of restorative material.[17] A rough restoration surface increases the coefficient of friction and may further aggravate the wear.[18] Rough surfaces enhance dental biofilm accumulation and staining, which can lead to gingival inflammation, increase the risk of secondary caries, decrease restoration surface shine and smoothness, and cause surface discoloration and degradation.[19]

A recent study on the effect of mastication on surface roughness of composite resins against zirconia and lithium disilicate ceramics reported that mastication can increase the surface roughness of composite resins against ceramics.[20]

Daryakenari *et al*.[21] evaluated the wear and surface roughness of Vita Mark II, e.max, Enamic, and Suprinity ceramics against tooth enamel in polished and glazed subgroups. They reported a reduction in surface roughness after wear in all ceramic and enamel specimens except for enamel against polished Enamic ceramic. The wear potential of polished and glazed ceramics was not significantly different. The highest wear occurred in the enamel against glazed Vita Mark II and Enamic ceramics. Another study used zirconia, lithium disilicate, and feldspathic porcelain ceramics for induction of tooth wear and showed that zirconia, followed by lithium disilicate, had insignificant surface roughness after polishing; however, feldspathic specimens had the highest surface roughness and caused enamel wear.[22] Another study regarding the wear behavior of different restorative materials reported that glazed zirconia-reinforced lithium silicate glass ceramic (Celtra Duo) had a depth of wear and volume loss similar to those of gold alloy, whereas the zirconia-reinforced lithium silicate glass ceramic prepared by bur had a significantly lower wear resistance immediately after milling.[23]

The best clinical approach, whether be reglazing or polishing after adjustment of the glazed surface, and their effect on wear and surface roughness of the opposing composite restoration remain unclear in the literature.

The purpose of this study was to assess the change in surface roughness of composite resin after wear against four CAD-CAM ceramics in a chewing simulator. The first null hypothesis was that glazing and polishing of CAD-CAM ceramics would have no significant effect on surface roughness of the opposing ceramic. The second null hypothesis was that glazing and polishing of CAD-CAM ceramics would have no significant effect on depth of wear of the opposing composite resin.

MATERIALS AND METHODS

This was an *in vitro* experimental study. The materials used in this study are presented in Table 1.

The study protocol was approved by the Ethics Committee of Babol University of Medical Sciences (IR.MUBABOL.HRI.REC.1400.166).

Preparation of ceramic specimens

The sample size of this study included 40 composite resin and 40 ceramic specimens (n = 10 in each subgroup).

All blocks were first sectioned into 2-mm thick slices by a precision sectioning machine (Nemo Fanavaran Pars, Mashhad, Iran) to obtain specimens measuring 2 mm × 5 mm × 5 mm. To standardize the sectioned surfaces by the CAD-CAM machine, they were polished with 800-grit silicon carbide paper. They were then glazed according to the manufacturers' instructions.

Table 1: Materials used in this study

Material	Manufacturer	Code	Composition
VITABLOCKS Mark II	VITA Zahnfabrik Germany	VM II	Milled feldspathic porcelain block fine feldspathic crystalline particles embedded in a glassy matrix Volume % 30 density (g/cm^3): 2.44±0.01 , small particle size: Average 4 μm
IPS e.max CAD	Ivoclar Vivadent, Germany	e.max	The lithium disilicate ceramic contained 57%–80% wt% SiO_2, 11–19 wt% Li_2O and other oxides such as K_2O, MgO, ZnO, Al_2O_3, P_2O_5
Celtra Duo	Dentsply Detrey GmbH, Germany	CD	Zirconia-reinforced lithium silicate ceramic block fine-grained lithium silicate, with high glass content, 10% zirconium oxide glass with completely dissolved zirconia lithium silicate crystallites: 500–700 nm
Vita Suprinity	VITA Zahnfabrik, Germany	VS	SiO_2, Li_2O, ZrO_2, K_2O, P_2O_5, Al_2O_3, CeO_2
Composite resin Filtek Z250	3M ESPE, USA	-	TEGDMA <1%–5%; Bis-GMA <1%–5%; Bis-EMA 5–10%; UDMA 5%–10% Zirconia/silica; 60 volume % inorganic fillers; particle size 0.01–3.5 m

CAD: Computer-aided design; TEGDMA: Triethylene glycol dimethacrylate ; Bis-GMA: Bisphenol-A-glycidyl methacrylate; Bis-EMA: Ethoxylated bisphenol-A dimethacrylate ; UDMA: Urethane dimethacrylate; VM II: Vita Mark II; CD: Celtra Duo

Primary glazing

Vita Mark II

Feldspathic specimens (Vita Mark II) were sintered after the application of the glazing agent (VITA Glaze LT, VITA Zahnfabrik, Germany) as instructed by the manufacturer (950°C, 10 min).

IPS e.max CAD

To glaze lithium disilicate specimens, the glazing agent (IPS e.max CAD Crystal/Glaze, Ivoclar Vivadent) was applied on the surface of specimens, and they were sintered in a furnace (840°C, 13 min).

Suprinity

The glazing agent (VITA AKZENT Plus, Germany) was applied on the surface of zirconia-reinforced lithium silicate specimens as instructed by the manufacturer, and they were completely crystalized in a furnace (840°C, 12 min).

Celtra Duo

The glazing agent (Dentsply Sirona Universal Glaze) was applied on the surface of zirconia-reinforced lithium silicate specimens according to the manufacturer's instructions, and they were fully crystalized in a furnace (820°C, 10 min).

Next, the specimen surfaces were abraded by a diamond fissure bur (No. 837F fine-grit; D + Z, Germany) to simulate a clinically adjusted restoration surface. The ceramic specimens were then randomly assigned to two subgroups (n = 5). One subgroup was reglazed and the other one was polished.

Polishing process

Vita Mark II

Aluminum-coated finishing discs (Sof-Lex discs; 3M ESPE) were used as instructed by the manufacturer starting from black color to light blue. In the first subgroup, final polishing was performed by a cup-shaped nylon brush and diamond finishing paste (Ultradent, Germany).

IPS e.max CAD

The ceramic kit recommended by the manufacturer (OptraFine, Ivoclar Vivadent) was used for finishing and polishing of specimens in this group in the following order:

- Light blue diamond finishers
- Dark blue diamond polishers
- Nylon brushes in conjunction with the diamond polishing paste
- Finishing was performed by a low-speed handpiece.

Suprinity

To smoothen the ceramic surface after finishing, the polishing system suggested by the manufacturer (VITA Suprinity Polishing set clinical) was used starting from diamond-coated pink to gray polisher.

Celtra Duo

After finishing, polishing discs (Sof-Lex discs, 3M ESPE, St. Paul, MN, USA) were used starting from coarse to medium and fine by a low-speed handpiece with mild-to-moderate pressure. Next, diamond polishing paste with a particle size smaller than 60 μm (Ultradent) was used with a bristle brush and latch-type handpiece at low speed.

Preparation of composite specimens

A rectangular polytetrafluoroethylene mold measuring 10 mm × 10 mm × 2 mm was used for the fabrication of composite resin specimens. Composite resin was cured for 20 s by a curing unit (VALO, Ultradent, USA) with 430–480 nm wavelength and 1000 mW/cm^2 light intensity.

To complete finishing and polishing, Sof-Lex (3M ESPE) finishing and polishing system (coarse, medium, fine, superfine) was used. Each disc was used for 20 s until a high gloss surface was achieved.

A total of eight groups of specimens were evaluated in this study as follows:

- Composite 1: Composite specimens against glazed e.max ceramic
- Composite 2: Composite specimens against polished e.max ceramic
- Composite 3: Composite specimens against glazed Vita Mark II ceramic
- Composite 4: Composite specimens against polished Vita Mark II ceramic
- Composite 5: Composite specimens against glazed Suprinity ceramic
- Composite 6: Composite specimens against polished Suprinity ceramic
- Composite 7: Composite specimens against glazed Celtra Duo ceramic
- Composite 8: Composite specimens against polished Celtra Duo ceramic.

Wear test

A chewing simulator (Nemo Fanavaran Pars, Mashhad, Iran) was used for the wear test. It applied a vertical force and sliding movements. The parameters used for this test included 49 N load, 0.7 mm sliding movement range, Crest Complete toothpaste as lubricant diluted 1:5, and 120,000 cycles.

Surface roughness assessment

The surface roughness of all composite resin and ceramic specimens was evaluated by a profilometer (Nemo Fanavaran Pars, Mashhad, Iran) after preparation and before the wear test. The results were reported quantitatively. The specimens underwent profilometry again after the wear test to compare their surface roughness (Ra value) before and after the wear test. One specimen from each subgroup was used for atomic force microscopy (AFM; Nanosurface, Switzerland) assessment [Figures 1 and 2].

Assessment of wear of specimens

Specimens in the subgroups that underwent surface roughness test were also scanned by a 3D scanner (l3Dscan, Germany) before and after the wear test, and the depth of wear in each subgroup was calculated by the Photoshop software (Adobe Photoshop CC 2015; Adobe, New York, USA). The initiation point of measurement was unworn specimen surface, and the final point was the deepest point in worn areas.

Data were analyzed by SPSS version 26 (SPSS Inc., IL, USA) using one-way and repeated measures two-way analysis of variance (ANOVA) followed by the Tukey's test at $P < 0.05$ level of significance.

RESULTS

In assessment of composite specimens, the lowest surface roughness after wear was recorded in the composite group against glazed Suprinity. According to repeated measures ANOVA, the surface roughness of composite specimens was significantly different before and after the wear test in both glazed Suprinity ($P = 0.048$) and Vita Mark II ($P = 0.026$) ceramic groups. The difference in before and after surface roughness values was not significant in any other group [$P > 0.05$, Diagram 1].

Assessment of surface roughness of ceramic specimens before and after the wear test showed a significant reduction in surface roughness of glazed and polished Vita Mark II and polished Suprinity ceramics ($P = 0.000$, $P = 0.013$, and $P = 0.037$, respectively) after the test; other ceramics did not experience a significant change in surface roughness [$P > 0.05$, Diagram 2]. Comparison of surface roughness of ceramics revealed a significant difference among them both before and after the wear test ($P = 0.018$). Table 2 compares the surface roughness of ceramic specimens before and after the wear test.

The depth of wear of ceramics ranged from 0.015 to 0.039 mm [Table 3]. According to two-way ANOVA, the effect of ceramic type on depth of wear was significant ($P = 0.017$). However, the effect of preparation method and the interaction effect of ceramic type and preparation method on ceramic wear depth were not significant ($P = 0.51$ and $P = 0.71$, respectively). Comparison of the depth of wear of composites in groups 1–8 revealed no significant difference ($P = 0.57$). The depth of wear of composites ranged from 0.088 to 0.359 mm. AFM micrographs show the surface topography of ceramic and composite specimens [Figures 1 and 2].

DISCUSSION

In assessment of surface roughness of composite specimens after the wear test, the results showed a significant reduction in surface roughness, compared with baseline, in both glazed Suprinity and Vita Mark II groups; however, the change in surface roughness was not significant in any other group. Thus, the first

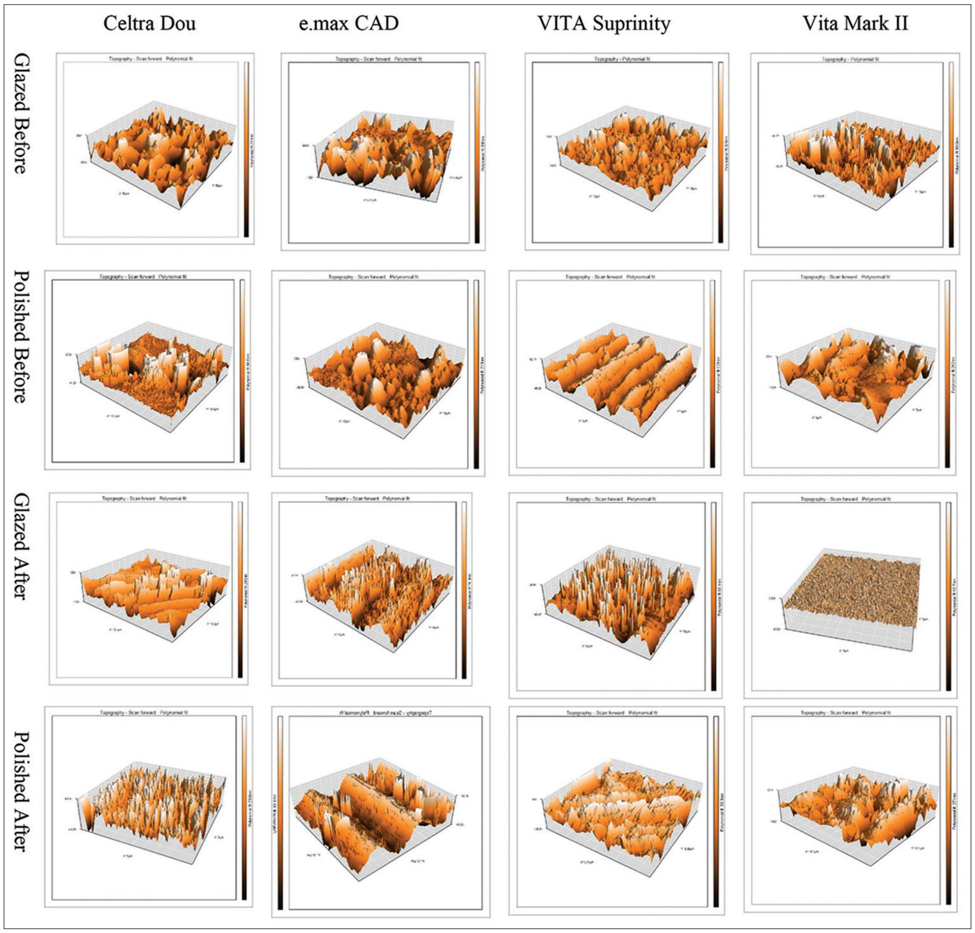

Figure 1: Atomic force microscopy micrographs of surface roughness of ceramic specimens before and after the wear test.

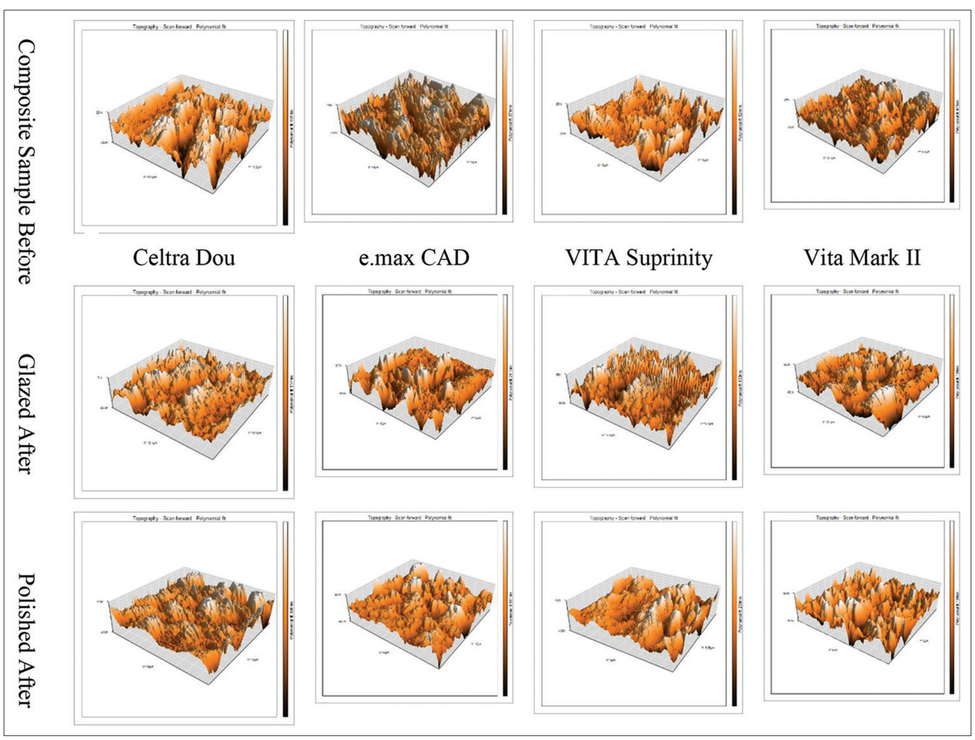

Figure 2: Atomic force microscopy micrographs of surface roughness of composite specimens against ceramics before and after the wear test.

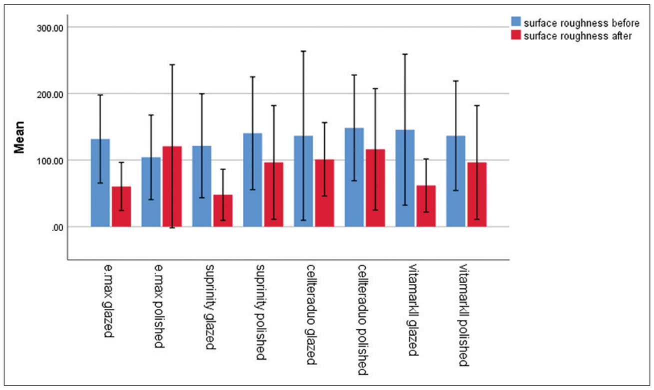

Diagram 1: Surface roughness of composite specimens against different ceramic specimens before and after the wear test.

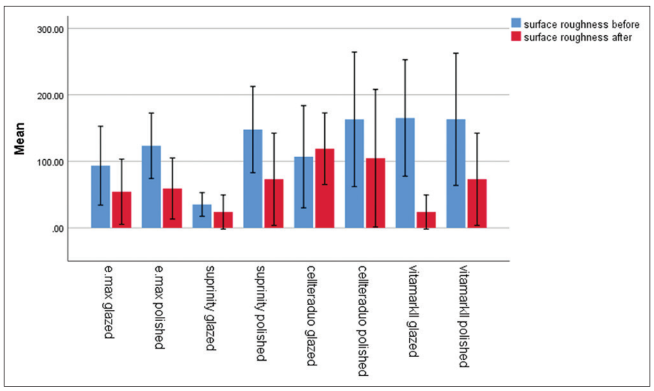

Diagram 2: Surface roughness of glazed and polished ceramics before and after the wear test.

null hypothesis of the study was rejected. The mean values of depth of wear were 0.161 and 0.214 mm in composites against glazed and polished ceramics, respectively, which were not significantly different. Thus, the second null hypothesis of the study was accepted.

In the present study, assessment of initial surface roughness of glazed and polished Vita Mark II, Suprinity, Celtra Duo, and e.max CAD ceramics prior to the wear test revealed the highest Ra value in glazed Vita Mark II and the lowest in glazed Suprinity. Similarly, Vichi *et al*.[24] reported a lower Ra value of Suprinity than e.max. In general, surface roughness of ceramics is affected by the type of ceramic and surface treatment. The microstructure of Suprinity, which contains smaller crystal volume and smaller crystal size, results in lower Ra of glazed ceramic.[25,26]

According to Kou *et al*.,[27] the Suprinity ceramic is expected to have higher polishability due to its microstructure and presence of zirconia; however, the opposite was observed in this study. Kou *et al*.[27] discussed that the presence of Zr and the composition of ceramic enable more efficient polishing. Vichi *et al*.[24] reported that polishing time affects the Ra value, and 60 s of manual finishing/polishing is the most efficient method for reduction of surface roughness of silica-based CAD-CAM ceramics. Their findings justify the higher Ra value of polished compared with glazed Suprinity in this study.

Table 2: Comparison of the mean surface roughness (Ra) of ceramic specimens before and after the wear test

Type of ceramic	Before (nm)	After (nm)
e.max		
Glazed	$93.56\pm47.69^{a,b,1}$	$54.35\pm39.45^{a,1}$
Polished	$123.50\pm39.57^{A,1}$	$59.26\pm36.95^{A,1}$
VS		
Glazed	$35.27\pm14.300^{a,c,1,*}$	$23.83\pm20.63^{a,1}$
Polished	$147.78\pm57.20^{A,1,*}$	$73.13\pm55.77^{A,2}$
CD		
Glazed	$106.91\pm61.86^{a,b,1}$	$119.07\pm43.31^{b,1}$
Polished	$163.18\pm81.43^{A,1}$	$104.77\pm83.18^{A,1}$
VM II		
Glazed	$165.31\pm70.48^{b,1}$	$23.83\pm20.63^{a,2}$
Polished	$163.31\pm80.01^{A,1}$	$73.13\pm55.77^{a,b,2}$

*Significant difference between glazed and polished groups. Different lowercase letters indicate significant differences in each column between glazed groups; different uppercase letters indicate significant differences in each column between polished groups; different superscript numbers indicate significant differences in each row. VM II: Vita Mark II; CD: Celtra Duo; VS: Vita Suprinity; IPS e max: IPS e.max CAD

In the present study, comparison of glazed and polished ceramics before and after the wear test revealed significantly lower surface roughness of glazed and polished Vita Mark II after the wear test, which was in agreement with the results of Daryakenari *et al*.[21] It should be noted that in this comparison, glazed Vita Mark II showed the highest initial surface roughness. Accordingly, Vita Mark II experienced the greatest change in surface roughness due to the wear test. High surface roughness of Vita Mark II can be related to the large size of its crystals. No significant difference was noted in initial surface roughness of other glazed and polished ceramics.

Comparison of surface roughness of glazed and polished ceramics after the wear test in each group revealed insignificant differences. Çakmak *et al*.[28] evaluated scanning electron microscopic images and reported that the superficial glaze layer is probably worn in contact with the antagonist material, and surface roughness changes as such. However, polished groups retain their surface properties (surface roughness). Thus, wear of the glaze layer and

Table 3: Depth of wear (mm) in composite and ceramic substrates

Groups	Composite wear depth		P	Ceramic wear depth		P
	Glaze	Polish		Glaze	Polish	
e.max	0.08±0.12	0.14±0.05	0.42	0.02±0.005[A]	0.01±0.005	0.13
VS	0.19±0.15	0.13±0.16	0.63	0.036±0.01[B]	0.03±0.02	0.77
CD	0.15±0.17	0.22±0.18	0.6	0.01±0.005[A]	0.02±0.01	0.26
VM II	0.21±0.14	0.35±0.5	0.54	0.02±0.008[A,B]	0.03±0.03	0.55
P	0.6	0.5		0.008	0.2	

Different uppercase letters indicate significant differences in the column. VM II: Vita Mark II; CD: Celtra Duo; VS: Vita Suprinity; IPS: e-max CAD

exposure of the underlying ceramic minimizes the difference between glazed and polished groups.

Assessment of surface roughness of composite specimens before and after the wear test revealed a significant reduction in Ra in composite specimens in both glazed Suprinity and Vita Mark II ceramic groups. It is probable that the Vita Glaze material confers a similar abrasive behavior to both Suprinity and Vita Mark II ceramics. Furthermore, the homogeneity of the microstructure of the Suprinity ceramic[29] and low percentage of the crystalline phase in Vita Mark II can play a role in reduction of surface roughness of the opposing composite.[23] Lawson *et al*.[30] discussed that achieving a smooth surface after polishing of ceramics mainly depends on the type of material rather than the type of finishing/polishing system used. In other groups, no significant difference was noted in Ra of composite specimens against the glazed and polished ceramics.

According to the present results, the Ra value in all composite subgroups before and after the wear test was clinically acceptable since it was lower than the reported threshold in the literature (200 nm) for plaque retention on the material surface.[31]

Assessment of the wear behavior of dental restorative materials is important from the clinical standpoint since this parameter can affect the appearance of restorations, change the inter-arch relations due to movement of teeth, decrease the vertical height of occlusion, reduce the masticatory function, and eventually lead to muscle fatigue.[32]

Çakmak *et al*.[28] stated that glazing/polishing of specimen surface had no significant effect on wear of the material itself or its antagonist, which was in line with the present findings. Furthermore, they found no significant correlation between the surface roughness and depth of wear of materials and their antagonists.[28] In the present study, the depth of wear was greater in the composite group against the polished Vita Mark II ceramic but had no significant difference with other groups. Contrary to this finding, Daryakenari *et al*.[21] reported that the depth of wear of the enamel substrate against glazed Vita Mark II was significantly greater than that in other groups. This finding can be due to differences in the type of substrate tested in the two studies.

Shimane *et al*.[33] discussed that in wear of two opposing materials, the softer material is worn easier than the harder material. Thus, wear of composite resin would be higher than ceramic. The present results confirmed this statement.

In the current study, comparison of surface roughness and depth of wear of glazed and polished ceramics and their opposing composite revealed no significant difference after the wear test. This finding encourages the clinicians to use the available polishing kits instead of reglazing in the clinical setting after occlusal or proximal adjustment of restorations. Accordingly, the time and cost would be saved.

Future studies are recommended to use different composite resins for better comparison of materials. Furthermore, 120,000 chewing cycles were applied in the current study, corresponding to 6 months of clinical service.[34] Further studies are required to apply a higher frequency of cycles to better simulate the clinical conditions. Comparison of staining of worn composites against ceramics should also be assessed.

CONCLUSION

1. The surface roughness of CAD-CAM ceramics evaluated in this study was affected by the type of material and type of surface treatment (glazing or polishing)
2. Surface roughness of composite specimens was not affected by the surface treatment of the opposing ceramic
3. The depth of wear of composite against CAD-CAM ceramics did not depend on the type of ceramic or type of surface treatment of ceramic (glazing or

polishing). Considering all the above, it appears that the use of CAD-CAM ceramic polishing kits is a safe alternative to reglazing of such ceramics.

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

REFERENCES

1. Li RW, Chow TW, Matinlinna JP. Ceramic dental biomaterials and CAD/CAM technology: State of the art. J Prosthodont Res 2014;58:208-16.
2. Takaba M, Tanaka S, Ishiura Y, Baba K. Implant-supported fixed dental prostheses with CAD/CAM-fabricated porcelain crown and zirconia-based framework. J Prosthodont 2013;22:402-7.
3. Ille CE, Moacă EA, Suciu M, Barbu-Tudoran L, Negruțiu ML, Jivănescu A. The biological activity of fragmented computer-aided design/manufacturing dental materials before and after exposure to acidic environment. Medicina (Kaunas) 2023;59:104.
4. Sarikaya I, Güler AU. Effects of different polishing techniques on the surface roughness of dental porcelains. J Appl Oral Sci 2010;18:10-6.
5. Anusavice KJ, Shen C, Rawls HR. Phillips' Science of Dental Materials. Saunders: Elsevier Health Sciences; 2012.
6. Bartlett D, Varma S. A retrospective audit of the outcome of composites used to restore worn teeth. Br Dent J 2017;223:33-6.
7. Borgia E, Baron R, Borgia JL. Quality and survival of direct light-activated composite resin restorations in posterior teeth: A 5- to 20-year retrospective longitudinal study. J Prosthodont 2019;28:e195-203.
8. Goodacre CJ, Bernal G, Rungcharassaeng K, Kan JY. Clinical complications in fixed prosthodontics. J Prosthet Dent 2003;90:31-41.
9. O'Brien WJ, Johnston WM, Fanian F, Lambert S. The surface roughness and gloss of composites. J Dent Res 1984;63:685-8.
10. Silikas N, Kavvadia K, Eliades G, Watts D. Surface characterization of modern resin composites: A multitechnique approach. Am J Dent 2005;18:95-100.
11. Mehl C, Scheibner S, Ludwig K, Kern M. Wear of composite resin veneering materials and enamel in a chewing simulator. Dent Mater 2007;23:1382-9.
12. Cavalcante LM, Masouras K, Watts DC, Pimenta LA, Silikas N. Effect of nanofillers' size on surface properties after toothbrush abrasion. Am J Dent 2009;22:60-4.
13. Lu H, Roeder LB, Lei L, Powers JM. Effect of surface roughness on stain resistance of dental resin composites. J Esthet Restor Dent 2005;17:102-8.
14. Kantorski KZ, Scotti R, Valandro LF, Bottino MA, Koga-Ito CY, Jorge AO. Surface roughness and bacterial adherence to resin composites and ceramics. Oral Health Prev Dent 2009;7:29-32.
15. Han JM, Zhang H, Choe HS, Lin H, Zheng G, Hong G. Abrasive wear and surface roughness of contemporary dental composite resin. Dent Mater J 2014;33:725-32.
16. Kon M, Kakuta K, Ogura H. Effects of occlusal and brushing forces on wear of composite resins. Dent Mater J 2006;25:183-94.
17. Momoi Y, Hirosaki K, Kohno A, McCabe JF. *In vitro* toothbrush-dentifrice abrasion of resin-modified glass ionomers. Dent Mater 1997;13:82-8.
18. Krejci I, Lutz F, Boretti R. Resin composite polishing – Filling the gaps. Quintessence Int 1999;30:490-5.
19. Al Khuraif AA. An *in vitro* evaluation of wear and surface roughness of particulate filler composite resin after tooth brushing. Acta Odontol Scand 2014;72:977-83.
20. Ho TK, Satterthwaite JD, Silikas N. The effect of chewing simulation on surface roughness of resin composite when opposed by zirconia ceramic and lithium disilicate ceramic. Dent Mater 2018;34:e15-24.
21. Daryakenari G, Alaghehmand H, Bijani A. Effect of simulated mastication on the surface roughness and wear of machinable ceramics and opposing dental enamel. Oper Dent 2019;44:88-95.
22. Amer R, Kürklü D, Johnston W. Effect of simulated mastication on the surface roughness of three ceramic systems. J Prosthet Dent 2015;114:260-5.
23. De Angelis F, D'Arcangelo C, Malíšková N, Vanini L, Vadini M. Wear properties of different additive restorative materials used for onlay/overlay posterior restorations. Oper Dent 2020;45:E156-66.
24. Vichi A, Fabian Fonzar R, Goracci C, Carrabba M, Ferrari M. Effect of finishing and polishing on roughness and gloss of lithium disilicate and lithium silicate zirconia reinforced glass ceramic for CAD/CAM systems. Oper Dent 2018;43:90-100.
25. Fasbinder DJ, Neiva GF. Surface evaluation of polishing techniques for new resilient CAD/CAM restorative materials. J Esthet Restor Dent 2016;28:56-66.
26. Mörmann WH. The evolution of the CEREC system. J Am Dent Assoc 2006;137:7S-13S.
27. Kou W, Molin M, Sjögren G. Surface roughness of five different dental ceramic core materials after grinding and polishing. J Oral Rehabil 2006;33:117-24.
28. Çakmak G, Subaşı MG, Sert M, Yilmaz B. Effect of surface treatments on wear and surface properties of different CAD-CAM materials and their enamel antagonists. J Prosthet Dent 2023;129:495-506.
29. Yilmaz EÇ. Investigation of two-body wear behavior of zirconia-reinforced lithium silicate glass-ceramic for biomedical applications; *in vitro* chewing simulation. Comput Methods Biomech Biomed Engin 2020;24(7):1-19.
30. Lawson NC, Janyavula S, Syklawer S, McLaren EA, Burgess JO. Wear of enamel opposing zirconia and lithium disilicate after adjustment, polishing and glazing. J Dent 2014;42:1586-91.
31. 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;13:258-69.
32. Ekfeldt A, Karlsson S. Changes of masticatory movement characteristics after prosthodontic rehabilitation of individuals with extensive tooth wear. Int J Prosthodont 1996;9:539-46.
33. Shimane T, Endo K, Zheng JH, Yanagi T, Ohno H. Wear of opposing teeth by posterior composite resins – Evaluation of newly developed wear test methods. Dent Mater J 2010;29:713-20.
34. Steiner M, Mitsias ME, Ludwig K, Kern M. *In vitro* evaluation of a mechanical testing chewing simulator. Dent Mater 2009;25:494-9.