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Effect of Simulated Mastication on the Surface Roughness and Wear of Machinable Ceramics and Opposing Dental Enamel

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Clinical Relevance

The new polishing systems for CAD-CAM ceramics including Vita Mark II, e.max, Suprinity, and Enamic can be good alternatives to reglazing, after clinical finishing, because the roughness and wear rate of both the ceramic and the opposing enamel will either not change or decrease.

SUMMARY

Objective: Computer aided design-computer aided machining (CAD-CAM) ceramic crowns are replacing ceramo-metal ones due to newly developed mechanical properties and esthetics. To obtain knowledge about their interactions due to polishing and occlusal contacts with the opposing dental enamel specimen, including surface roughness and wear, the three-body wear simulation was investigated.

Methods and Materials: The surface roughness (RA) and wear rate (mm) of four CAD-CAM blocks with different compositions including Vita Mark II, e.max, Suprinity, and Enamic, after two surface treatments of glazing and polishing, and their opposing enamel specimens, were investigated using a mastication simulator and atomic force microscope.

Results: The roughness of all ceramic and to a greater extent enamel samples, with the exception of enamel opposing polished Enamic samples, was decreased after wear. No significant difference in wear was evident for the ceramic samples between the glazed and polished treatments. Lower wear rates were recorded only for polished Vita Mark II and polished Enamic in comparison to the glazed ones.

Conclusion: The newly developed polishing systems for CAD-CAM ceramics can be good alternatives to reglazing, because the roughness and wear rate of both the ceramic and the opposing enamel will either not change or decrease.

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INTRODUCTION

Ceramic crowns are readily replacing conventional ceramo-metal ones, claiming esthetic advantages and mechanical and clinical performance. The contemporary combination of computer intelligence and updated dental materials has led to a new series of more accurate ceramic crowns with less laboratory and chair time, called computer aided design-computer aided machining (CAD-CAM) technology.[1-4]

Despite the precise fit and accuracy of the CAD-CAM crowns, the intraoral finishing step would presumably leave a rougher surface, enhancing plaque and stain accumulation.[5] Newly introduced ceramic polishing systems, however, claim to be capable of creating a desirable ceramic surface.[6,7] The properties and composition of the ceramic and the polishing protocol induce the degree of their effectiveness.[7] What seems to be the most effective protocol is using a porcelain polishing kit with diamond polishing pastes.[6,7]

Feldspathic CAD-CAM blocks [$(Na_2K)AlSi_3O_8$] were among the first machinable porcelains with excellent esthetics. They are used for different purposes such as veneers and crowns.[8-10] One such block used today is Vita Mark II (VITABLOCS Mark II, Zahnfabrik, Bad Säckingen, Germany). A more durable lithium disilicate block ($Li_2Si_2O_5$) was later introduced in 2006 with higher strength (IPS e.max CAD, Ivoclar Vivadent, Liechtenstein, Austria).[11] A hybrid block of ceramic (86% wt feldspathic network) integrated with polymer network, called VITA Enamic (Zahnfabrik), has superior elasticity and flexural strength and is claimed to have similar wear rate as dental tissues. It is specifically suggested for conservative preparations as it can be manufactured in very thin thicknesses (0.2-0.5 mm).[12] Another CAD-CAM block has lithium disilicate glass composition, strengthened with zirconia (10% wt), called Vita Suprinity (Zahnfabrik) (Table 1).

Conventional feldspathic porcelain causes enamel wear.[13] Zirconia and, to a less extent, lithium disilicate were reported to have minimal surface roughness after polishing compared with feldspathic ceramic, which had the highest roughness.[14,15] Feldspathic ceramics have in turn represented the most enamel wear.[15] Zirconia caused lower wear rates when polished rather than the glazed or veneered forms of zirconia or lithium disilicate.[16] Overall, enamel specimen wear is the highest when the opposing ceramic is glazed.[17]

The aim of this *in vitro* study was to evaluate the surface roughness and wear rate of different CAD-CAM ceramics and opposing dental enamel in a wear test. Therefore, the null hypothesis was that there would be no statistically significant difference in the average roughness and wear between different CAD-CAM ceramics and the opposing dental enamel specimen.

METHODS AND MATERIALS

Specimen Preparation

In this laboratory study, four CAD-CAM ceramic blocks were used to prepare ceramic bases for mastication simulation. VITABLOCS Mark II (VMII) was a feldspathic ceramic. IPS e.max CAD and VITA Suprinity were two lithium disilicate glass ceramics, with the exception that Suprinity contains 10% by weight zirconia. The last block used was VITA Enamic, a feldspathic porcelain modified with acrylate polymer. The materials and their manufacturer are summarized in Table 1.

Two single crown blocks were used to prepare 10 slices of each ceramic. The blocks were mounted in epoxy resin bases and precisely cut into 2-mm-thick slices using a Precision Sectioning machine (Nemo, Mashhad, Iran) using a water stream coolant. Cutting speed for the Suprinity and e.max ceramics was set at 2 mm/hr, and for VMII and Enamic, the speed was 10 mm/hr. The blocks were assigned to eight subgroups (n=5) according to their surface treatments (finished and polished or finished, polished, and reglazed).

After block preparation, all specimens were glazed and crystallized (10 minutes, 950°C for VMII, 13 minutes, 840°C for e.max, and 12 minutes, 840°C for Suprinity) as suggested by the manufacturer (Table 1). The Enamic slices were etched with 5% hydrofluoric acid (VITA Ceramic ETCH) and silanated (VITASIL). The glaze (VITA Enamic glaze, predominantly methyl methacrylate) was applied and light cured (Bluephase C8; Ivoclar Vivadent) for 60 seconds. A fine grit fissure diamond bur (D&Z, Kalletal, Germany) was used to imitate the clinical finishing procedure of the ceramics. VMII blocks were polished using black to light blue grit, Sof-Lex ceramic polishing disks (Table 1), using each disk for 1 minute. The Optrafine polishing kit was used to polish the e.max specimens. Light blue and dark blue diamond polishers were applied for 1 minute each, followed by nylon brushes in conjunction with the diamond polishing paste. The Suprinity and Enamic blocks were polished with the pink diamond polisher for 1 minute and then the gray polisher for another minute. Half of the specimens in each ceramic group were reglazed after being polished.

The enamel specimens (n=40, 2×2 mm) were cut from the buccal surface of sound human lower first

Table 1: *CAD-CAM Ceramic Blocks, Manufacturers, Glazing, and Polishing Systems*

CAD-CAM Block	Chemical Composition	Manufacturer	Glazing	Polishing System
VITABLOCS Mark II	SiO_2, Al_2O_3, Na_2O, K_2O, CaO, TiO_2	Zahnfabrik, Germany	VITA AKZENT Plus spray	Sof-Lex discs, 3M ESPE, USA
IPS e.max CAD	SiO_2, Li_2O, K_2O, P_2O_5, ZrO_2, ZnO, Al_2O_3, MgO	Ivoclar vivadent, Austria	IPS e.max CAD Crystall Glaze	Optrafine, Ivoclar vivadent, Austria
VITA Suprinity	SiO_2, Li_2O, ZrO_2, K_2O, P_2O_5, Al_2O_3, CeO_2	Zahnfabrik, Germany	VITA AKZENT Plus spray	VITA SUPRINITY Polishing Set clinical, Zahnfabrik, Germany
VITA Enamic	SiO_2, Al_2O_3, Na_2O, K_2O, B_2O_3, CaO, TiO_2 Methacrylate polymer network	Zahnfabrik, Germany	VITA Enamic Glaze	VITA Enamic Polishing Set clinical, Zahnfabrik, Germany

molars, with no visible caries, cracks, or abnormalities. The surfaces were polished using silicon carbide sand paper from course to fine grit (800-1200), respectively, until surfaces were evened out.

Wear Test

Enamel specimens were fixed by cyanoacrylate on the force applying handle of the mastication simulator (Pedeb 1; Dental Material Research Center, Babol University of Medical Sciences, Babol, Iran), and the ceramic block was placed in the base of the simulator, immersed in a tooth paste solution (Crest; Procter & Gamble, Cincinnati, USA) (one part to five parts distilled water) as a third party lubricant. A static 2-kg vertical force was applied by the upper handle while moving in a circle (10 mm diameter) for 120,000 cycles.[18,19]

Roughness and Wear Measurement

The surface roughness (Ra) of all specimens (enamel and ceramic) was measured using an atomic force microscope (AFM, nanosurf, easyScan 2 FlexAFM; Nanoscience Instruments, Inc. Woburn, USA), before and after the wear test (Figures 1 and 2). The surfaces were also scanned before and after the test using a three-dimensional scanner (CEREC Inlab; Dentsply Sirona, Salzburg, Austria). The obtained images through the scanner were then overlapped, and the height loss and wear of the tested materials were precisely measured using the ruler tool in Photoshop software (mm, Adobe Photoshop CC 2015; Adobe, New York, USA The starting point of the measurement was the original surface of the specimen, whereas the end point was the depth of the worn surface in ceramics or the new worn surface of the enamel specimen.

The acquired data were analyzed by the SPSS20 software (IBM, New York, USA) using independent-samples *t*-test, analysis of variance, and Tukey *post hoc* analyzing tests.

RESULTS

Roughness

According to Table 2, the surface roughness of the polished VMII presented the highest roughness before and after wear, which was statistically significant. This roughness was higher than that of the glazed VMII. The roughness of all ceramic groups decreased after the wear test, although this

Table 2: *Mean Roughness (Ra) and SD of Ceramic Surface Before and After Wear*[a]

Ceramic	Surface Treatment	Before Wear (Ra)	After Wear (Ra)
VITABLOCS Mark II	Glazed	1.9262 ± 0.8026^{aA}	1.0214 ± 0.7226^{aA}
	Polished	77.7668 ± 8.8988^{bA}	35.6404 ± 11.2324^{bB}
IPS e.max CAD	Glazed	10.9404 ± 1.5379^{cA}	10.0024 ± 1.4791^{cdA}
	Polished	13.0676 ± 2.7249^{cdA}	5.7216 ± 3.34^{acdA}
VITA Suprinity	Glazed	9.508 ± 0.8039^{cA}	6.3526 ± 0.7573^{cdA}
	Polished	17.7348 ± 1.6906^{dA}	4.2794 ± 1.7903^{adB}
VITA Enamic	Glazed	12.2802 ± 0.7424^{cA}	6.7726 ± 1.8005^{cdB}
	Polished	8.499 ± 0.4502^{cA}	4.9456 ± 0.8132^{adA}

[a] *Equal superscript lowercase letters indicate no statistically significant differences within each column. Equal superscript uppercase letters indicate no statistically significant differences within each row.*

Figure 1. *Ceramic roughness measurement before and after the wear test by AFM (Ra).*

amount was only significant in the VMII polished, Suprinity polished, and Enamic glazed groups.

As presented in Table 3, the primary roughness of all the enamel samples was not significant (p=0.959). After the wear test, a noticeable decline of roughness was observed in the enamel specimens in all groups, although it was insignificant for the polished Enamic antagonists. The VMII ceramic demonstrated the highest amount of enamel specimen surface roughness change when glazed or polished.

Wear

According to Table 4, there was no significant difference in wear recorded comparing the glazed or polished group of each individual ceramic type. In

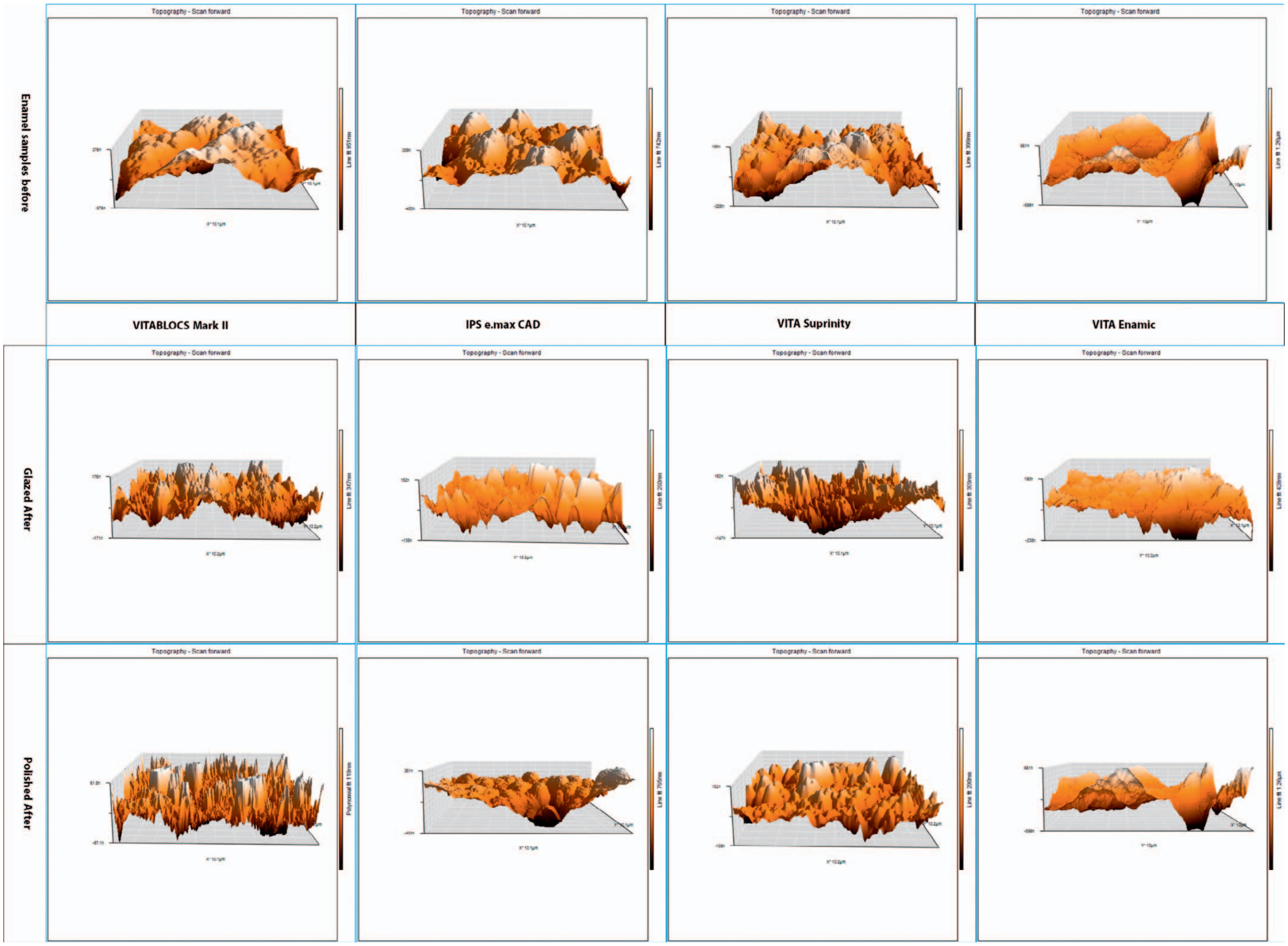

Figure 2. *Enamel roughness measurement before and after the wear test by AFM (Ra).*

the glazed group, the highest wear was for the Suprinity group, which was only significant over that of the e.max group ($p=0.04$). The same was true about the Suprinity polished group, with a significant difference from the VMII group ($p=0.02$).

According to Table 5, no significant difference was recorded for the e.max and Suprinity glazed groups ($p=0.25$), whereas the rest of the wear rates between the enamel specimens opposing the glazed ceramics were noticeable ($p<0.01$). A significant enamel

Table 3: *Mean Roughness (Ra) and SD of Opposing Enamel Surface Before and After Wear[a]*

Opposing Ceramic	Surface Treatment	Before Wear (Ra)	After Wear (Ra)
VITABLOCS Mark II	Glazed	$153.0584 \pm 25.1985^{aA}$	16.0172 ± 12.6506^{aB}
	Polished	154.624 ± 15.7964^{aA}	11.6506 ± 7.9549^{aB}
IPS e.max CAD	Glazed	141.989 ± 16.4766^{aA}	$35.7532 \pm 15.4292^{abB}$
	Polished	$158.3184 \pm 35.6935^{aA}$	$50.6798 \pm 31.5919^{abB}$
VITA Suprinity	Glazed	$124.1968 \pm 23.5288^{aA}$	$58.5862 \pm 24.2284^{abB}$
	Polished	$157.8234 \pm 35.2398^{aA}$	$24.6616 \pm 18.0767^{abB}$
VITA Enamic	Glazed	$156.2248 \pm 24.4407^{aA}$	82.5626 ± 24.4421^{bB}
	Polished	$156.4388 \pm 24.0212^{aA}$	$143.0776 \pm 21.6449^{cA}$

[a] *Equal superscript lowercase letters indicate no statistically significant differences within each column. Equal superscript uppercase letters indicate no statistically significant differences within each row.*

Table 4: *Mean Ceramic Wear (mm) and SD After 120,000 Wear Cycles[a]*

Ceramic Treatment	VITABLOCS Mark II	IPS e.max CAD	VITA Suprinity	VITA Enamic
Glazed	0.148 ± 0.1257[abA]	0.088 ± 0.0216[aA]	0.222 ± 0.0614[bA]	0.124 ± 0.0114[abA]
Polished	0.050 ± 0.200[aA]	0.092 ± 0.5070[abA]	0.164 ± 0.09127[bA]	0.084 ± 0.026[abA]

[a] *Equal superscript lowercase letters indicate no statistically significant differences within each row. Equal superscript uppercase letters indicate no statistically significant differences within each column.*

specimen height was lost compared with opposing glazed VMII and glazed Enamic ceramics.

VMII and Enamic ceramics demonstrated a significantly lower enamel specimen loss when polished rather than glazed.

DISCUSSION

The results of this study show that the enamel specimens that were tested against the polished Enamic blocks had the smallest amount of roughness change, presumably showing the least enamel specimen surface alterations. The most vigorous amount of enamel specimen roughness change was evident in VMII and polished Suprinity antagonists, although all the other groups with the exception of the polished Enamic group became significantly rougher ($p<0.01$).

The primary roughness of the polished VMII was significantly and noticeably higher than all the other ceramic groups, depicting an insufficient polishing process. The highest amount of enamel specimen loss was also evident in the VMII groups; however, the rougher surface of the polished VMII caused significantly less enamel specimen height loss in comparison to the glazed treatment. In a study, unpolished and unglazed VMII resulted in similar enamel specimen and ceramic wear as a pressed ceramic (IPS Empress), with similar composition (Leucite crystals/feldspathic porcelain). However, the results were significantly higher than gold and Dicor machinable ceramics.[20]

Overall, the wear of the enamel specimens was less evident when the antagonist ceramic was polished, which can be a positive motivation toward the polishing systems of modern CAD-CAM ceramics. The only group with significantly higher enamel specimen wear in only the polished ceramic groups was the e.max. In a similar study of wear, all ceramic specimens presented similar and wear-friendly properties, against the enamel specimen and compared with the control group. The ceramics included e.max CAD and LAVA Plus Zirconia.[21] In our study, the polished Suprinity group and the polished e.max group were worn statistically in a similar fashion. Because the methodology and material components of the tested specimens were different, the grounds for comparison are limited.

The highest amount of enamel specimen wear was observed in the VMII glazed and to some extent glazed ceramics. Polished VMII ceramics were the group with the least height loss after the wear test. This would suggest that polished VMII ceramics would not be worn after clinical function; in return, the opposing dental enamel specimen would suffer height loss to a greater extent. The glazed VMII would also cause a great deal of enamel specimen loss, but the ceramic would be almost equally worn. Whether that is a matter of significance remains to be seen.

The best results were seen in the polished Enamic and all Suprinity ceramics, with the least enamel specimen wear. This is definitely a plus finding in addition to other superior benefits of these newer CAD-CAM systems. In fact, Suprinity ceramic specimens were more likely to be worn than the antagonist enamel specimens. Also, despite that the enamel specimen was significantly worn in the Enamic polished group, the surface roughness properties remained unchanged. In one study, e.max CAD and Enamic demonstrated signs of abrasive wear, which was similar to the enamel specimen control group.[22] In another study on the wear and roughness of several restorative materials,

Table 5: *Mean Enamel Wear (mm) and SD After 120,000 Wear Cycles[a]*

Opposing Ceramic Treatment	VITABLOCS Mark II	IPS e.max CAD	VITA Suprinity	VITA Enamic
Glazed	2.000 ± 0.247[aA]	0.702 ± 0.0917[bA]	0.498 ± 0.1696[bA]	1.224 ± 0.1078[cA]
Polished	1.252 ± 0.139[aB]	1.048 ± 0.1735[aA]	0.396 ± 0.0687[bA]	0.470 ± 0.2214[bB]

[a] *Equal superscript lowercase letters indicate no statistically significant differences within each row. Equal superscript uppercase letters indicate no statistically significant differences within each column.*

e.max CAD and Enamic ceramics were indifferent in antagonist enamel specimen wear, although the polishing technique was very different to this study. VMII and e.max ceramics had lower roughness than the zirconia and Enamic specimens, whereas they were not different from the enamel specimen group. However, the surface roughness was measured after a toothbrush simulator and not the wear test.[23]

The methodology and the newer materials used in the present study limits the comparison of the results to other wear simulating studies. It is best to further investigate the efficacy of other polishing systems and protocols on a wider variety of ceramics.

CONCLUSIONS

According to the findings of the present study, the CAD-CAM ceramic polishing systems are a safe and accommodating replacement for the reglazing of the studied ceramic restorations, because the roughness and wear rate of both the ceramic and the opposing enamel specimen will either not change or decrease. Further investigation for other ceramic and polishing systems is necessary to reach a unanimous conclusion in the case of all ceramics.

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Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of approval of the Babol University of Medical Sciences in Mazandaran, Iran.

Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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