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Effect of Different Storage Media on the Surface Roughness of two CAD/CAM Materials

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Abstract

Purpose: To assess the surface roughness of two of CAD/CAM Ceramic materials: Lithium disilicate and Resin nanoceramic, after being stored in three media: Instant coffee, Citric Acid and Artificial saliva.

Materials and methods: A total number of 42 slices cut by low speed diamond saw with water coolant of IPS e.max CAD & Cerasmart ceramic blocks (n=21 for each material) and shade A3. The samples were divided into three subgroups (n=7 for each storage medium): Sub-Group 1: stored in instant coffee, Sub-Group 2: stored in citric acid, Sub-Group 3: stored in artificial saliva. All samples were subjected to thermocycling at 5000 cycles between 5 and 55 degrees in deionized water with a dwell time of 30 seconds, and transfer time of 10 seconds. Surface roughness values were determined by a surface Profilometer. The data were analyzed using One Way ANOVA test followed by Tukey`s Post Hok test for multiple comparisons. The significant level was set at $P \leq 0.05$.

Results: Immersion in different media had no significant difference on surface roughness of tested ceramics. However, polished Cerasmart had less surface roughness than glazed IPS e.max CAD. The Null hypothesis proposed was that aging in different storage media will not affect the surface roughness of Cerasmart and IPS e.max CAD was accepted.

Conclusion: Immersion in instant coffee, citric acid and artificial saliva did not alter the surface roughness of IPS e.max CAD and Cerasmart.

KEY WORDS: Hybrid ceramic, Lithium disilicate, Surface roughness.

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Introduction

The Computer-aided design and computer-aided manufacturing (CAD/CAM) technology progression enabled the creation of esthetic restorations. Fabrication of tooth-colored CAD/CAM restorations was common by composite resin blocks. (1) As a substitute to ceramic blocks, the polymer-infiltrated ceramic network (PICN) material, VITA Enamic (VE), and resin nanoceramic blocks, Lava Ultimate (LU), and GC CeraSmart (CS) have been established. PICN properties are meeting between those of highly filled composite resin and porcelain properties. (2) Resin nanoceramic blocks were informed to have improved or similar fracture toughness in addition to advanced wear potential than usually used composite resin materials.(3) Furthermore, the belongings of those materials mechanically were realized to be similar to those of enamel (4) and they were proposed to eradicate the behavior of brittleness of all-ceramics when subjected to loading. (5) Certainly, these materials have been made of ceramic and resin material composed together and have properties close to each other. (5) Nevertheless, the resin-ceramic hybrid materials are not likely to be exposed to glazing with heat treatment because of their resin content. Therefore, finishing with other techniques have importance for resin-ceramic hybrid materials to recreate a surface comparable to glazed ceramic surface.(5)

Since surface roughness also has an effect on surface free energy, surface roughness of dental materials is studied widely in dental literature. (6) Which means that, rough surfaces of dental materials are the reason for an increased surface free energy resultant in additional plaque creation. (7) On the other hand, smooth surfaces of dental materials may be the reason for easy surface cleaning and decrease microbial growth. As a result, the material's surface roughness has reputation related to performance of the dental restorations clinically on the long term. (8) Surface roughness worsens the aesthetic value and biomechanical value of dental restorations, increasing vulnerability to aging. (9) Surface roughness won't rise plaque retention only (10) and source of abrasive damage to opposite dentition, (11) but it will also be deteriorated by the occurrence flaws on surface, which can cause material to fail. (12)

In daily life a lot of different beverages and foods are consumed in different quantities, temperatures, colors and compositions with each has a different effect on the intraoral structures. For example, coffee and cola are from the most commonly consumed soft and hot beverages. (13) Moreover, Citric acid has a common consumption in day-to-day life as it presents in numerous foods and beverages as lemon, oranges, limes, kiwis, grapefruits, apples, straw berries, cherries, pears, and raspberries and vegetables such as potatoes, mushrooms, peas, tomatoes, and asparagus. (14)

Studies that examined the surface roughness of modern-day CAD/CAM materials contrary to commonly used colored drinks are inadequate. Consequently, the determination of this in vitro study was to determine the surface roughness changes of newly developed CAD/CAM materials after immersed in instant coffee, citric acid and artificial saliva. The null hypothesis of this study was that aging in different storage media will not affect the surface roughness of cerasmart and e.max.

Materials and Methods

I. Materials used in this study:

Ceramics

Table (1): Showing the ceramics used in the study

Type	Brand	Manufacture	Composition
Lithium dislicate	IPS e.max CAD	Ivoclar vivadnt	SiO2 and additional components Li_2O, K_2O, MgO, Al_2O_3, P_2O_5 and other oxides
Hybrid ceramic	Cerasmart CAD/CAM	CER, GC, Tokyo, japan	flexible nanoceramic matrix is composed of 71 wt. % silica (20nm) and barium glass (300nm) nanoparticles

Solutions

a. Instant coffee: Nescafe classic were used in this study to evaluate the effect on color stability and surface roughness.
b. Citric acid: citric acid powder was dissolved in distilled water with 2% concentration.
c. Artificial saliva: composition (mmoles/L): $CaCl_2$ (0.7), $MgCl_2.6H_2O$ (0.2), KH_2PO_4 (4.0), KCl (30), NaN_3 (0.3), and HEPES buffer (20). The protease inhibitors (mmoles/L) were: benzamidine HCl (2.5), ε -amino-n caproic acid (50), Nethylmaleimide (0.5), and phenylmethylsufonyl fluoride (0.3).

II. Methods

Samples grouping and study design:

A total number of 42 slices were cut of IPS e.max CAD/CAM & Cerasmart ceramic blocks (n=21 for each material). The samples were divided into two groups.

- Group I: e.max
- Group II: Cerasmart

And then divided into three subgroups according to the storage media (n=7 for each storage medium).

- Subgroup 1: instant coffee.
- Subgroup 2: citric acid.
- Subgroup 3: artificial saliva.

Samples preparation:

The ceramic slices were prepared from e.max CAD/CAM block and cerasmart CAD/CAM (12.4x14.5x1.5mm) shade A3 by low-speed diamond saw isomet 4000*(*Isomet 4000, Buehler, Lake Bluff, H, USA.) with water coolant. The final thickness of the specimens was confirmed with digital caliper for standardization.

Glazing and polishing of samples

The ceramic slices were subjected to polishing and glazing according to manufacturer's instructions. Crystallization and glaze firing in one step with glaze paste for Group I e.max CAD, and polishing of Group II cerasmart by manual sequential grits polishing kit for hybrid ceramics.

Measurements

The surface roughness was measured using a surface profilometer (TR 220 Surface Roughness Tester, TIME Group, Pittsburgh, PA, USA) using a cut-off value of 0.25 mm. Three measurements were recorded. The measurements were done as follows; one measurement in the center of the specimen and the other two measurements were to the right and the left of the central one, guided by marks done at the bottoms of the specimens. The average surface roughness (Ra) was determined for each specimen. These measurements were taken before immersion as baseline and repeated at the end of the immersion period (which is equal to 1 year) in the different storage media.

Thermocycling

Thermocycling is a common method of artificial enhanced aging of ceramics because it duplicates the oral environment as an extrinsic factor. The water aging method includes standardized thermal variations with baths ranging from 5 to 55ºC for several cycles.THE-100 SD Mevhatronic thermocycler Germany was used in this study. All samples were subjected to thermocycling at 5000 cycles between 5 and 55 degrees in deionized water with a dwell time of 30 seconds, and transfer time of 10 seconds.

Staining Solutions preparation

The instant coffee solution was prepared according to the manufacturer's instructions by using 1.8 g of coffee and 150 mL of hot water (Nescafe classic). The Specimens were stored for 12 days in containers in an incubator temperature 37°C. Solutions were renewed every 12 hours in order to prevent bacterial contamination. After 12 days each of the sample surfaces was washed under the running water then with distilled water then dried with a sterile cotton. The Citric Acid solution was prepared in a lab according to the manufacturer's instructions by using citric acid powder dissolved distilled water giving 2% citric acid solution. The Specimens were stored for 4 hours continuous in containers in an incubator temperature 37°C. After 4 hours each of the sample surfaces was washed under the running water then with distilled water. The Artificial saliva solution was prepared in a lab according to the manufacturer's instructions to have pH 7. The Specimens were stored for 7 days in containers in an incubator temperature 37°C as shown in **Figure (1)**. Solutions were renewed every 2 days in order to prevent bacterial contamination. After 7 days each of the sample surfaces was washed under the running water then with distilled water.

Figure (1): Specimens in Incubator

Results

Statistical analysis; in this invitro study all the collected data were presented as means, mean difference and standard deviation (SD) values. Comparison between three different groups (instant coffee, citric acid and artificial saliva) was performed by using One Way ANOVA test followed by Tukey`s Post Hok test for multiple comparisons. For group I e.max and group II cerasmart comparison between before and after storage was performed and revealed insignificant difference in instant coffee, citric acid and artificial saliva, with group I resulted with the highest roughness after immersion in citric acid and group II resulted with the highest roughness after immersion instant coffee. In addition, the comparison between three storage solutions were performed for both groups using One Way ANOVA test which revealed insignificant difference between them regarding before and after and difference between before & after, followed by Tukey`s Post Hot test for multiple comparisons which revealed in significant difference (means with the same superscript letters) as $P > 0.05$.

Furthermore, comparing between group I & II was performed by using Independent t-test which revealed that group I was significantly higher than group II ($P<0.05$) regarding different storage solutions (instant coffee, citric acid and artificial saliva) in before storage, after storage and difference between before and after storage as presented in **Table (2)**.

Table (2): Comparison of surface roughness between group I & II regarding before and after storage in solution and difference roughness:

		Group I (Emax)	Group II (Cersmart)	P value
		M ± SD	M ± SD	
Before	Instant coffee	0.45 ±0.09	0.16 ±0.08	0.001*
	Citric acid	0.45 ±0.08	0.12 ±0.03	0.001*
	Artificial Saliva	0.46 ±0.11	0.11 ±0.01	0.001*
After	Instant coffee	0.48 ±0.09	0.16 ±0.05	0.001*
	Citric acid	0.52 ±0.08	0.15 ±0.03	0.001*
	Artificial Saliva	0.48 ±0.11	0.12 ±0.01	0.001*
Difference	Instant coffee	0.03 ±0.009	0.007 ±0.002	0.001*
	Citric acid	0.07 ±0.013	0.03 ±0.001	0.001*
	Artificial Saliva	0.02 ±0.006	0.01 ±0.003	0.001*

M: Mean. SD: Standard Deviation.
*P: Probability * P<0.05*

Discussion

Lately, lithium disilicate systems have brought attention to extensive investigations. (15,16) and a quantity of such glass-ceramics have been clinically used broadly. (17) Therefore, one of the ceramics used in this study was IPS Emax CAD as a type of lithium disilicate ceramics. The development of CAD/CAM systems and software proposes several advantages in clinical practice. (18) Indirect composite CAD/CAM blocks as (Cerasmart) were nominated in the present study due to their strengths such as the capability to modify and repair the surface effortlessly and their stress absorbing properties. (19)

About the glazing and polishing for samples; in order to gain smooth and standard surfaces, for group I glazing actions were carried out according to manufacturer's recommendations. (10) For group II smart system for smart work flow by no glazing, no firing, the final steps for an aesthetic restoration are made easier with easy option of manual polishing. (20) Thermocycling was achieved as a process for aging alike to that used in the study by Acar et al (2016) the thermocycling period (5000 cycles) is equivalent to 6 months of functioning intraorally. (21)

Ra parameter value for roughness is the most commonly used for assessment of surface consequently, it was used in this study to have easy comparison with other studies. (12) The reason for choosing the stylus profilometer in this study to measure the surface roughness was its surface individuality as contacting the surface is often a benefit in dirty environments while, using non-contact way may measure impurities in instead and so this method is not sensitive to surface reflectance or color. Moreover, its resolution is admirable as the tip radius of the stylus can be as minor as 20 nanometers so can measure thin films, meaningfully improved than white-light optical profiling. Vertical resolution is classically sub-nanometer as well. Stylus profilometer also permits outstanding measurement repeatability, easy to use (fast, simple), cheaper than other methods, extended life, durable and upgradeable. (14)

In an incubator all specimens were stored in instant coffee solution at 37°C for 12 days, which is corresponding to 1 year of coffee consumption. (22) Using citric acid by storing samples in 2% citric acid solution for 4 continuous hours and kept in incubator which simulates 1 year in vivo as **Demirel et al (2005),** mentioned 8 hours simulates 2 years.(14,23) Furthermore, Using artificial saliva for 7 days resembling 1 year in vivo as **Demirel et al (2005),** mentioned 14 days simulates 2 years.(14,23) Artificial saliva was chosen as a replacement for of human whole saliva to minimalize the inter-individual variation in salivary protein content, and their uncertainty extra-orally.(24)

The results of the current study revealed that Comparison between group I (e.max) & group II (cerasmart), group I which was glazed was significantly higher than group II which was polished ($P<0.05$). **Oliveira-Junior et al. (2013)** stated same conclusion through their study thus, the manually polished glass CAD/CAM ceramics encouraged lower surface roughness than did the glazed dental ceramics. Moreover, small pores could be found in the glazed samples, showing that glazing promotes roughness values increased when compared to polished surfaces.(10) Changes in roughness values are the highest in the glazed group (e.max) and that may be related to the initial higher mean roughness value, favoring the buildup of extrinsic substances differently from polished group (cerasmart). (25) Moreover, mechanical polishing system is considered beneficial in comparison with glazing concerning roughness and have achieved adequately smooth and polished surface.(25)

The most significant changes are found in the glazed groups immersed in citric acid may be clarified by the low pH, and the groups immersed in instant coffee by the raised temperature, factors that may disturb the mechanical and physical properties of ceramics. Moreover, the acid pH of these solutions may cause dissolving of the silica, with a resulting loss of alkaline ions and corrosion of the surface, which may have potentiated the degradation of the glaze and resulted in an increase in roughness. (25,26) However, regardless of whether the ceramic was polished or glazed, changes were detected. This effect possibly occurred because of termination of the silica network through the action of H_3O^+ and OH^- ions and the H_2O molecules that act by breaking the silica molecules (Si-O-Si) and selective leakage of alkaline ions; these mechanisms seem to occur in combination. The loss of elements such as Si, Al, Na, K, and Zr from the ceramic material has been reported.(25) Many studies revealed that means of polishing is able to make a final ceramic surface having comparable or improved roughness than glaze-fired ceramic surfaces.(10,27,28) Other studies presented opposing data, **Brentel et al.(2011)** concluded that polishing with rubber points and after it polishing by felt disks saturated with a fine-aluminum oxide particle caused a biofilm formation alike to that existing with a glazed ceramic surface, however, the surface is still more rough and more hydrophobic. (29)

It was realized by different studies that glazing provides enough surface smoothness in ceramic restorations, (30,31) but others verified that polishing with instruments as diamond rotary and rubber abrasives can similarly offer clinically satisfactory smoothness which is similar to our study. (31) Concerning group I (Emax) comparison between before and after storage was performed and revealed insignificant difference in instant coffee, citric acid and artificial saliva. Furthermore, concerning group II (Cerasmart) comparison between before and after storage was performed and revealed insignificant difference in instant coffee, citric acid and artificial saliva. In support with this results **Abdelrahman (2019),** stated in his study that coffee treated cerasmart the control group and the finish and polish group recorded the surface roughness (Ra) statistically non-significant ($p>0.05$) lower mean value than before immersion in coffee. (32)

Limitations of the present study contain limited investigation time. Immersion for amount of time which mimics 1 year intraorally representing a partial lifespan for a prosthetic restoration and limited clinical simulation. Furthermore, thermocycling examined only standard temperatures. The outcomes of this study should be supported with clinical studies. Additional clinical and in vitro studies are essential to evaluate the vulnerability of hybrid dental ceramic and resin nanoceramic materials to surface roughness by other beverages and nutrients. Finally, the additive outcome of other common aging procedures as the tooth brushing was not studied. Future investigations for the effect of added contributing factors such as smoking also should be evaluated.

Conclusion

Within the limits of this in vitro study, the following conclusions were concluded:

1. Immersion in different staining solutions had no pronounced effect on surface roughness of both lithium disilicate and hybrid ceramic.
2. Regardless of storage polished hybrid ceramic has less surface roughness than glazed lithium disilicate.

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