International Journal of Current Advanced Research
ISSN: O: 2319-6475, ISSN: P: 2319-6505, Impact Factor: 6.614
Available Online at www.journalijcar.org
Volume 8; Issue 10 (A); October 2019; Page No.20105-20109
DOI: http://dx.doi.org/10.24327/ijcar.2019.20109.3919

Research Article

EFFECT OF ORAL ENVIRONMENTAL CONDITIONS ON SURFACE ROUGHNESS AND FATIGUE STRENGTH OF PORCELAIN FUSED TO METAL RESTORATIONS

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A R T I C L E I N F O

Article History:

Received 10th July, 2019
Received in revised form 2nd August, 2019
Accepted 26th September, 2019
Published online 28th October, 2019

Key Words:

The cola and orange juices may affect the surface quality as well as fatigue strength of ceramics.

A B S T R A C T

Ceramic restorations are widely used to achieve esthetics but the durability and long-term success of ceramics in oral cavity may be affected by the oral environmental condition. The cola and orange juices may affect the surface quality as well as fatigue strength of ceramics. This research study was done to evaluate the immersion of low fusing ceramic in artificial salvia, cola and orange juice on surface roughness and fatigue strength. A total of 90 ceramic discs were equally distributed into three groups as follows:-Group1: immersed in artificial saliva adjusted at pH 7 for one year.Group2: immersed in cola for 4 hours.Group3: immersed in orange juice for 4 hours. The pH was measured for the three solutions using pH meter. The degradation of porcelain was tested by measuring the surface roughness using the profilometer. The fatigue strength was tested using Llyoid testing machine. Results were analyzed using ANOVA and least significant differences at 95% level of confidence. The results showed that the surface roughness increased when ceramic was immersed in acidic medium. The surface roughness was accompanied by a statistically significant decrease in strength property of low fusing ceramic (p=0.019). It was concluded that low fusing ceramic is not an inert material and the acidic saliva leads to increase in surface roughness and decrease of fatigue strength.

INTRODUCTION

Ceramic is preferable in dentistry because of its esthetics, biocompatibility, translucency and durability. Porcelain restoration when immersed in alkaline solution or in saliva for long time may affect its strength or the outer surface topography. The acidulated phosphate fluoride gel can be applied topically as fluoride rinses, fluoride containing differences and fluoride gel applied by the trays for caries prevention[1].

Fluoride gel application for the treatment of dentin hypersensitivity by precipitation of calcium phosphate to occlude the dentinal tubules was studied.

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Also the effect of topical application gel on the tensile strength and surface topography of low fused porcelain were studied.It was concluded that, fluoride application lead to increase in surface roughness and decrease the tensile strength[1].

Porcelain with different Lucite contents and clinical indications were used. Materials with higher Lucite showed significantly higher strength properties when compared to materials with low Lucite content [2].

When ready-made zirconia posts with different treatments were studied. The results showed a significant decrease in fracture load of zirconia posts. [3]

The flexural strength, reliability and mode of fracture of reinforced In-Ceram veneered with conventional porcelain were evaluated. It was found that the weakness of veneering porcelain may be compensated by the strength and toughness of core materials[4].

The effect of different surfaces as ground and over glazed on the strength of ceramic core was studied. It was found that the over glazed ceramics are significantly stronger than the ground ones [5].

Albakry *et al* measured the fracture toughness and hardness of IPS-Empress, Empress 2 and an experimental ceramic. They showed a significant difference with IPS-Empress. The fracture toughness of IPS has increased with decrease in hardness which should be of clinical benefit[6].

Dremmond *et al* tested the changes of high Lucite ceramics, pressed porcelain, low fusing porcelain and an experimental ceramic by the oral environment and cyclic loading. It was found that there is a significant decline in the durability of all ceramic restorations[7]. They also tested the flexural strength of lithium disilicate ceramic showing significant improvement than those of high Lucite ceramics and low fusing porcelain[7].

Also, Scherrer *et al* evaluated the fracture toughness of Doceram exposed to water for a long time. It was found that there was an increase of fracture toughness of Duceram after aging in water[8].

The solubility of glass ceramics by different types of calcium fluoride was investigated. A direct proportional relation was found between solubility and the amount of fluoride.[9]

An investigation by Milleding *et al* was done to monitor the ion dissolution of glass-ceramics when immersed in 4% acetic solutions for 18 hour. They concluded that a large amount of sodium, potassium, magnesium, silicon and aluminum were leached out. Ion leakage of glass ceramics was greater than that of crystalline alumina and zircon ceramics[10].

Reclaru and Meyer 1994[11] stated that the corrosion rate increases as the acidity of saliva increases. The mouth is continually subjected to fluctuation in the pH due to various food and drinks. The pH value may not be the same in different areas of the mouth.,this creates concentration cell corrosion.

Calcium, Phosphate and hydroxyl ions are present in saliva and plaque fluid [12]. There is a critical pH for every person under which the tooth structure will dissolve .This pH vary according to the amount of calcium and phosphate in the saliva. Meanwhile the behavior of the ions depends on the critical pH of the individual and their saturation in saliva. If the saliva is supersaturated, the ions will be deposited on the tooth surface. If it is undersaturated a dissolution of the ions from the tooth surface starts until the solution becomes saturated[12].

Although the biocompatibility of zirconia made it used in bone replacement, difficulties in shaping it did not help its use in dentistry. However, new machines were developed to produce direct ceramic restorations from zirconia [13, 14, 15].

During bleaching, the effect of 35% carbamide peroxide for 30 min/week for 3 weeks on the surface smoothness of ceramic was studied by Moraes et al. It was found that there was no significant change during all test periods[16].

Comparison was made by Bulter *et al* to study the effect of distilled water and Carbamide peroxide solution on the smoothness of feldspathic porcelain and all ceramic. The results indicated a significant increase of surface irregularities of specimens immersed in solution and distilled water when compared to that of the control specimens[17]. They also found that hydroxyl-apatite was dissolved. This process continued till water saturation with hydroxyl-apatite. The dissolution rate was the same as the precipitation[17]. Also Demirhanoglu and Sahin found that there is a risk of surface deterioration of dental ceramics when exposed to ammonium bifluoride or hydro fluoric acid[18].

Surface properties of glazed low-fusing ceramic exposed to artificial saliva were evaluated by Nadia et al., indicating statistical significance on micro hardness, crack propagation and fracture toughness[19].

When Yamamoto *et al* evaluated the relation of crack development in micro-glass ceramic reinforced with composite resin and surface roughness, they found no significance [20].

While Zaninik *et al* found out in their study that the surface roughness of feldspathic ceramic has significant lower values than that of alumina and zirconia based ceramic. But there was no significance in the roughness values of high crystalline content ceramic [21].

The objective of this study was: To assess the impact of exposing low fusing ceramic to artificial saliva, cola and orange juice on Surface Roughness and Fatigue Strength of ceramic.

Limitation of the study

This study was done in vitro and it was difficult to simulate the oral mouth conditions to evaluate the real effect.

MATERIALS

Low fusing ceramic material was used in this study

Table 1 Low fusing ceramic materials used in this study

Materials	Manufacturer	Shade
Duceram ceramic material Feldspathic porcelain	Duceram, Dental Gm bH Rosbach, Germany	A3

Specimen preparation

A split cylinder with an outer diameter of 5cm and 5mm height with a central hole of 15mm in diameter and 8mm thickness to make porcelain disc .The ceramic powder was blended with the proper liquid to fill the cylindrical hole and then condensed. Porcelain disc was then removed, fired, and auto glazed.

Sample size

A total of 90 porcelain disc specimens were divided into three groups, 30 for each group as follows:

Group1: Immersed in artificial saliva adjusted at pH 7 for one year.
Group2: Immersed in cola for 4 hours.
Group3: Immersed in orange juice for 4 hours.
The specimens were immersed in cola and orange solution for 4 hours representing one year intake of the solution. This was done according to Demirhanoglu and Sahin18. Then the specimens were washed by water for one minute and dried with compressed air for one minute.

The immersion was done in glass tubes containing 250ml of the test solution. The measurements were done later after immersion in different test solutions. Then surface roughen and fatigue strength were measured.

Preparation of artificial saliva

Artificial saliva was prepared according to Nadia *et al* 19 which consisted of 0.4gm sodium chloride, 1.21 potassium chloride 0.78gm sodium, hypo sulfide, 1gm urea and 1000ml de-ionized water.

Adjustment of the pH of saliva

The artificial saliva was modified to pH 7 by the addition of concentrated hydrochloric acid drop by drop until the required pH value using glass electrode pH meter*. The specimens were placed in fabricated saliva medium for four hours.

pH measurements

Glass Electrode Digital pH meter* was used for measuring the pH value for each solution used in this study. A 30ml of each solution was placed in a glass cup and then the pH of each solution was measured

Surface roughness measurement

The surface roughness of the tested specimens (Ra) was measured by using profilometer**. Ra is the arithmetic mean of depth or height of five readings of the test specimens. The mean value was calculated tabulated and statistically analyzed for all the test specimens immersed in different solutions.

Fatigue strength test

Fatigue strength was measured after immersion in different solutions. Fatigue strength of test specimens were measured by cyclic compression loading with a load of 100 N and measured by Lloyed*** testing machine using a computer software. The cyclic loads were applied until fracture of ceramic specimen. The loads were collected, tabulated and the mean cyclic compression strengths and standard deviation in MPa were calculated. Data was analyzed using ANOVA and compared by least significant difference at 95% level of confidence.

* Micra processor pH meter 537 w, T.W. Wissenschaflick tcchnische workstan weilheim Germany.
** Perthometer KMK, Mahr perthem CSD west Germany.
*** Loyed instruments, LRX plus, LG. 5KN. Atradmark of Ametek Inc. Englan.

RESULTS

The pH measurements

The mean pH values of the different solutions and the statistical analysis used in this study were shown in table 2 & 3 and represented photographically in Fig.1.

****The surface roughness measurements***

The surface roughness for porcelain specimens after immersion in different solutions were recorded in table 4 and represented in Fig. 2 & Fig. 3. Results revealed that the least rough surface was in case of the groups immersed in artificial saliva followed by the groups immersed in orange juice and highest in case of groups immersed in cola solution with a highly statistically significant difference between all of them.

Table 2 pH values of the solutions utilized in this study.

	Solution	pH value	F
I.	Artificial Saliva	7.00 to 7.30	*
II.	Orange Juice	4.25 to 0.11	
III.	Cola	3.20 to 0.15	

Table 3 Least significant difference.

	Solution		Orange	Cola
I.	Artificial Saliva	--	*	**
II.	Orange Juice		--	*
III.	Cola		--	--

--Indicate no significant difference
*Indicate significant difference
**Indicate highly significant

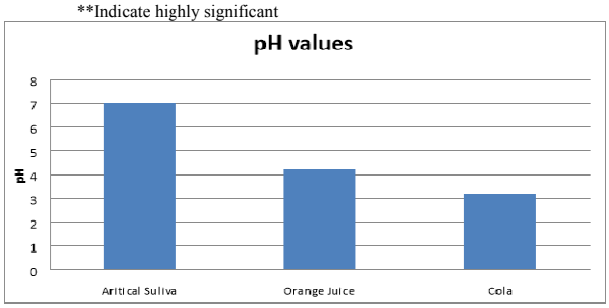


Fig 1 pH values of different solutions used

** Surface roughness measurements.

Surface roughness for porcelain specimens after immersion in different solutions were recorded in table 4 and represented in Fig. 2 & Fig. 3. Results revealed that the least rough surface was in case of the groups immersed in artificial saliva followed by the groups immersed in orange juice and highest in case of groups immersed in cola solution with a highly statistically significant difference between all of them.

Table 4 Surface roughness values in mm of all tested groups**.**

Group	Mean and standard duration	F	p
I. Artificial saliva	0.35 I 0.013	*	p=0.019
II. Orange juice	0.64 I 0.015		
III. Cola	0.73 I 0.020		

p value (0.019) with a high significant difference between group I, II and III
p>0.05 with No significant difference between group II and III

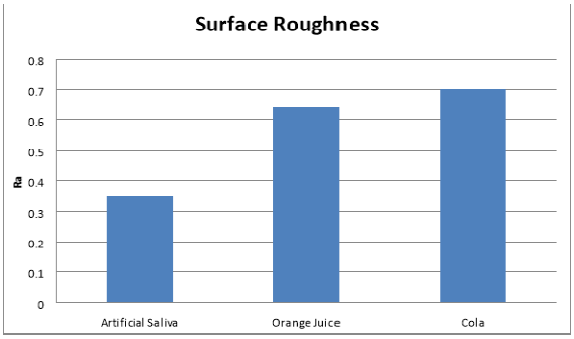
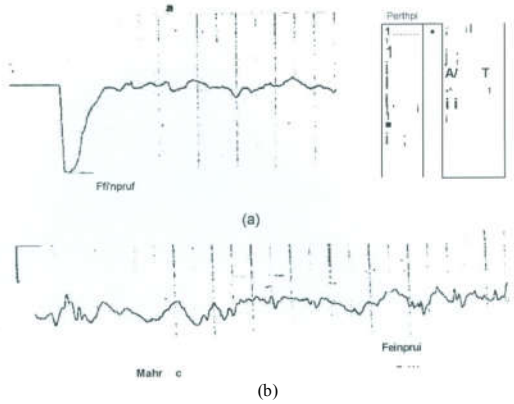
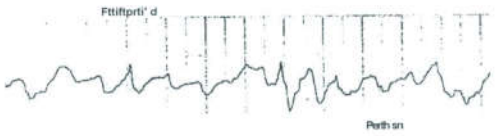


Fig 2 Values for surface roughness of test groups



(b)



(c)

Fig 3 Surface tracing of tested specimens immersed in:

(a) Artificial saliva
(b) Orange Juice
(c) Cola

******Fatigue Test***

LIoyed mechanical testing machine was utilized. A cyclic load was applied at frequency of 100 N until fatigue. The testing machine was controlled by computer. The mean value of cyclic compressive strength for the tested group were recorded in table 5 and represented in Fig 4. The highest cyclic load values were in case of group II and least value in case of group III.

Analysis of variance was done to compare the groups. It showed a high significant difference at p< 0.01 on comparing group I, II and III. There was no significant difference among group II and III (p>0.05).

Table 5 Cyclic compressive strength values in MPa of the tested groups

Group	Mean and standard deviation	F	p
I. Artificial saliva	15.32 I 1. 5	**	p<000*
II. Orange juice	10.92 I 0.89		***
III. Cola	10.20 I 1.1		***

* ANOVA indicated significant difference between all tested groups
** p value indicated high significance among group I , II and III.
***No significant difference between group II and III (at p> 0.05)

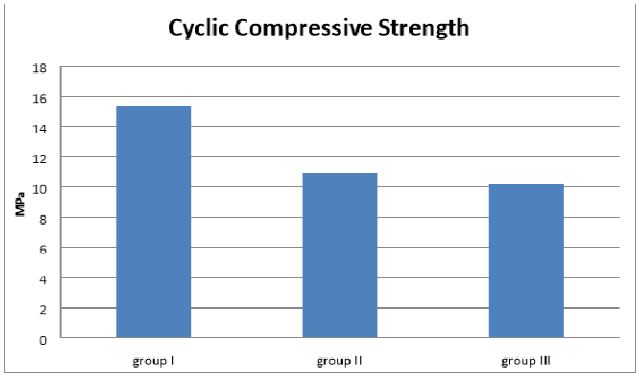


Fig 4 Cyclic compressive values of tested groups

DISCUSSION

In the present investigation, the surface texture of porcelain was changed and was accompanied by decrease in the fatigue strength when immersed in acidic solution. The acidic solution was increase the surface roughness when compared with that of artificial saliva.

Ra measurement of surface roughness of the low fusing porcelain immersed in different solution was measured by profilometer. The oral cavity has threatening conditions for dental materials. The pH of saliva depends on food and juice intake and saliva composition with degradation of ceramic, the roughness of the ceramic surface was increased as well as decreasing the facture resistance of ceramic material[22].

This study showed that, surface roughness increased when immersed in acidic medium which is in agreement with the results of park and Heo 2004[23] who stated that dissolution of porcelain when immersed in alkaline solution was more than when immersed in acidic solution.

McCabe and Angus 2000[24] stated that the strength properties of feldspathic porcelain are affected by glass matrix and not by crystalline phase. Also the strength properties are affected by presence of irregularities on the surface.
Some authors [25, 26] revealed that the surface roughness was not the only factor which affects the strength property but there are also other factors such as porosity, microstructure, residual stresses and surface defect. They also found that, the surface roughness was accompanied by significant decrease in strength properties of low fusing dental porcelain. This may be contributed to stress concentration.

DunnB[27] found that immersion of low fusing ceramic in alkaline salt lead to increase the strength due to the formation of compressive outer lamina which he contributed it to ionic exchange. This is in accordance with Denry et.al[28], and Seghi R et.al 1990[29] who stated that the flexure strength of regular dental ceramic increased up to 80% by ionic exchange. While Milleding et.al[30] stated that the dental ceramics are inert in a water surrounding and mentioned that the water erosion of low fused dental ceramic was affected by the leaching out of Na+ and K+. That low degradation of low fusing ceramic even occurred in distilled water. But when McCraken[31] studied the chemical durability of ceramic materials, he found that the chemical durability of ceramic material was affected by composition, microstructure and by the composition of the corrosive medium.

Obstacles

1. Machining the holder to measure the fatigue strength value
2. Difficulty in observing the initial radial crack formations due to high surface roughness
3. Making Porcelain specimens free from voids

CONCLUSIONS

From the previous investigation, it was concluded that:

1. Low fusing ceramic is not inert when immersed in aqueous solution or acidic solution.
2. Acidic saliva when compared with neutral saliva caused significant changes in surface topography and fatigue strength of low fusing ceramic.
3. The surface roughness was affected by the pH values of the storage media.
4. Decreasing pH led to increase the surface roughness as well as decreasing fatigue strength properties of low fusing ceramic.

Recommendations

The porcelain is not an inert material but leached out of some of its elements even when immersed in water or acidic solutions and future measures should be taken to account for the affected properties.

Acknowledgments

The authors gratefully acknowledge and thank the Deanship of Scientific Research, King Abdulaziz University (KAU), Jeddah, Saudi Arabia, for providing financial support through a research project grant (Grant No. *9-7/429)*

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How to cite this article:

Mohamed T. Hamed *et al* (2019) ' Effect of Oral Environmental Conditions on Surface Roughness and Fatigue Strength of Porcelain Fused to Metal Restorations', *International Journal of Current Advanced Research,* 08(10), pp. 20105-20109.
DOI: http://dx.doi.org/10.24327/ijcar.2019.20109.3919