Surface Roughness of Polished Translucent Zirconia after Immersion in Different Beverages and Temperatures

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Abstract

Monolithic translucent zirconia has currently increased its popularity as a restorative material. Exposure of the intraoral restoration to beverages people consume on a daily basis is inevitable.

This study observed the effects of different beverages and temperature on surface roughness of polished translucent zirconia. The specimens were prepared and randomly divided into 8 groups: 2 temperatures (5 and 25°C) and 4 beverages (Distilled water, Orange juice, Red wine, and Coffee). The surface roughness (R_a) was measured with a non-contact profilometer. The R_a before and after immersion in beverages were compared by paired-t test. The mean difference of surface roughness of each group was compared by two-way ANOVA.

The results showed that immersion polished translucent zirconia in beverages for 168 hours were not significantly affected to R_a. The types of beverage and temperatures were not significantly affected. Thus, the surface roughness of polished translucent zirconia was not altered by daily consumed beverages at 5 and 25°C.

Experimental article (J Int Dent Med Res 2023; 16(4): 1449-1453)

Keywords: Beverages, Polished, Surface roughness, Temperature, Zirconia.

Received date: 26 August 2023 **Accept date:** 03 October 2023

Introduction

Nowadays dental zirconia has been widely used for various indirect restorations. They are known for their excellent physical properties, namely compressive strength, chemical resistance, and biocompatibility. However, the esthetics of older generation of zirconia might be considered as inferior to that of predominantly glass ceramics due to their optical properties.[1] The major advantage of monolithic zirconia restorations are that they require minimal preparation and the risk of chipping of veneering porcelain is eliminated. Manufacturers have launched newer generations of high-translucent zirconia to enhance the esthetics for monolithic zirconia restorations while maintaining most of its desirable physical properties, including compressive strength, chemical stability, and biocompatibility.[2,3]

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The phase 'During try-in procedure of translucent monolithic zirconia restorations, alteration of the glazed material is inevitable since clinical adjustments are often necessary for desirable proximal and occlusal contact.' should be changed to 'To accomplish desirable occlusal and proximal contacts, adjustment on the glazed surface of zirconia restorations are inevitable.'

The removal porcelain glaze from the restoration often results in an increase in surface roughness which consequently, may compromise mechanical strength and induce more plaque accumulation, especially in contact areas.[4] Changes in surface roughness may also cause irregular and diffuse light patterns which might affect the color and appearance of the restoration, thus compromising esthetics.[5]

When polished zirconia is being exposed to the dynamics of the oral environment it is vulnerable to changes in temperature, pH, and of course fluids. A previous study conducted by Kukiattrakoon et al, in 2011 which studied the alteration in surface roughness of restoration suggested that degradation of the altered restoration may result from various food ingredients or beverages with low pH values.[6] It is presumed that hydroxyl ion (OH-) from aqueous solution may infiltrate and further result in surface grain degradation, before progressing deeper into the inner bulk of the restoration. The process of degradation in which hydroxyl ions from aqueous solution dissolute surface grains of zirconia is known as 'Low Temperature Degradation' (LTD).[7] Combination of acidic agents and the process of low temperature degradation are well-known causative factors that alters the surface roughness of zirconia restoration, leading to wear of antagonists and plaque accumulation. [8]

Degradation of surface grains is inevitable after prolonged service of zirconia restorations in the oral environment. As mentioned earlier, this is the result from subjection to mechanical forces and exposure to multitude of changes in temperatures and pH of the oral environment.[9] Many previous studies were investigated the surface roughness of glass ceramic. However, studies about surface alteration of zirconia restoration under the influence of temperature combined with beverages is very limited. Thus, the object of this study was to investigate the effect of different beverages and temperatures on surface roughness of polished translucent zirconia.

Materials and methods

The 5Y-PSZ translucent zirconia discs (VITA YZ® XT White, Vita Zahnfabrik, Germany) were milled into square-shape specimen with the size of 8x8x3 mm^3 using 5-axis milling machine (DWX-51D, Roland DGA Co, USA) for a total of 120 specimens. The milled specimens were sintered at 1450°C for 120 minutes, according to the manufacturer's instruction, by dental sintering furnace (Sintra Plus, Shenpaz, Israel). The sintered specimens were then cleaned with distilled water in ultrasonic bath (VGT-1990, QTD, China) for 5 minutes. From there on, the specimens were polished by coarse zirconia polishing bur (94018c, Komet USA, USA) followed by fine zirconia polishing bur (94018f, Komet USA, USA) respectively with the constant load, same direction, number of polishing strokes, and a single operator.

The specimens were randomly divided into 8 groups (4 beverages and 2 temperatures). The beverages that were used in the test were distilled water, orange juice, red wine, and coffee (Table 1). The temperature of the beverages was controlled at 5°C and 25°C in order to represent them at cold and room temperatures. The silicone jigs were fabricated for each specimen for locating the tested area which would be performed before and after the immersion in beverages.

The specimen surface roughness was analyzed by non-contact 3D profilometer (InfiniteFocus SL, Alicona Imaging GmbH, Austria). The specimens were tilted 10-15° for least scattering of light during testing. The center of the specimens was analyzed within the area of 0.4x0.4 mm^2. The average surface roughness (R_a) before immersion in beverages was recorded as R_{a1}. Then, the specimens were immersed in 10 mL of different beverages in petri dishes for 168 hours at 5°C and 25°C. The beverages were refreshed every 12 hours with refreshing time less than 3 minutes. The specimens were cleaned with distilled water prior to immersion in refreshened beverages. The pH meter (ORION 2-star Benchtop pH meter, Thermo Fisher Scientific, USA) was used to confirm the pH of the refreshed beverages was constant throughout the test.

After immersions, the specimens were cleaned with distilled water in ultrasonic cleaner for 5 minutes and incubated at 37°C for 24 hours, to dry the specimens. The surface roughness of specimens was then investigated and recorded as R_{a2}. The mean different of surface roughness of each specimen was calculated by equation $\Delta R_a = R_{a2} - R_{a1}$.

The data was analyzed with IBM SPSS 22 (IBM, Chicago). The normal distribution of surface roughness (before immersion, after immersion, and mean difference) each group was analyzed by 1-Komolgorov Smirnoff (1-KS) test. The surface roughness before and after immersion in each group was compared with paired t-test. The mean difference of surface roughness between group was analyzed by Two-way ANOVA at 95% confidence level.

Results

The result of 1-KS test showed that surface roughness was normally distributed in all the tested groups (Table 1). Paired t-test showed that the mean surface roughness of before and after immersion in beverages was not statistically significant in every group ($p>0.05$) (Table2).

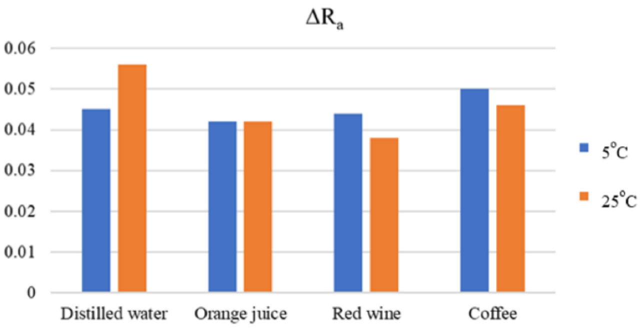

Figure 1. Mean different of surface roughness in each group.

Beverages	pH	Manufacturer	Lot no.
Distilled water	7.00	NP Chem (NP Chemical Supply Co., Ltd, Thailand)	-
Orange juice	3.59	Tipco (Tipco food Co., Ltd, Thailand)	20:23A09
Red wine	3.61	Quincho (Central valley, Chile)	21352
Coffee	6.22	Nescafé Blend and Brew (Nestlé Thai Ltd, Thailand)	22650526KB

Table 1. Details of beverages using in this study.

Levene's test showed normal variance between groups. The two-way ANOVA showed types of beverage and temperatures did not significantly affect the mean difference of surface roughness ($p>0.05$) (Table 3). The graph of ΔR_a in each group was showed in Fig 1.

Beverages	Temperature (°C)	Mean surface roughness (SD)		Pair t-test
		Before immersion (R_{a1})	After immersion (R_{a2})	Sig
Distilled water	5	0.930 (0.138)	0.976 (0.135)	.072
	25	0.831 (0.153)	0.887 (0.154)	.076
Orange juice	5	0.854 (0.203)	0.896 (0.212)	.257
	25	0.744 (0.115)	0.786 (0.146)	.102
Red wine	5	0.772 (0.230)	0.816 (0.213)	.184
	25	0.889 (0.264)	0.927 (0.263)	.332
Coffee	5	0.906 (0.152)	0.956 (0.122)	.076
	25	0.931(0.182)	0.977 (0.239)	.205

Table 2. Mean surface roughness (SD) in µm before and after immersion in different beverages.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2060.730	7	294.390	.033	1.000
Intercept	163928.103	1	163928.103	18.635	<.001
Beverages	1314.592	3	438.197	.050	.985
Temperatures	3.208	1	3.208	.000	.985
Beverages * Temperature	742.929	3	247.643	.028	.994
Error	633367.671	72	8796.773		
Total	799356.503	80			
Corrected Total	635428.400	79			

Table 3. Two-way ANOVA of Mean different of surface roughness (ΔR_a).

Discussion

Zirconia restorations have increased their popularity due to its improved esthetics together with many desirable mechanical and physical properties. The conventional zirconia which consisted of 3% yttria to stabilize the tetragonal phase of zirconia (3Y-TZP) was opaque, less esthetics when compared to the more translucent glass ceramics.[10] Thus, the translucent zirconia was recently developed to decrease the opacity of the restoration by increasing the yttria content to 5% mol. The increased yttria content resulted in changes of the crystalline structure of zirconia with the presence of cubic crystals in addition to the already present tetragonal crystals. This zirconia are known as Partially stabilized zirconia (5Y-PSZ). They possess greater translucency compared to 3Y-TZP, hence could be used in areas of esthetic concerns, namely in the anterior region of the oral cavity. However, the mechanical properties were compromised due a decrease in transformation toughening. [11,12]

The surface of zirconia could be finished by glazing and polishing. However, most zirconia restorations were polished and then eventually glazed after laboratory fabrication.[13] Though zirconia restorations were fabricated utilizing digital workflow, discrepancies of the dimension could occur from numerous factors (e.g. shrinkage from sintering, accuracy of scanner, and accuracy of milling machine).[14-16] Thus, intraoral adjustment after try-in procedures could be anticipated. Following the course adjustment, the adjusted surface must been smoothened to decrease the wear of opposing teeth, and plaque accumulation by polishing with zirconia polishing kit.[17] Thus, the polished surface zirconia was selected in this study.

From the previous studies, the surface roughness of glazed ceramic restoration was affected by the beverages and temperatures. The daily consumed beverages usually consisted of various types of acid. Orange juice contains citric, malic, and ascorbic acid.[18] Coffee contains chlorogenic, quinic, citric, acetic, lactic, malic, phosphoric. [19] Red wine contains tartaric, malic, citric, succinic, and acetic acid.[20] The acidic containing beverages were reported as chelating agent that degrade and dissolution the silicate network. Consequently, this resulted increased surface roughness of glass ceramic restorations.[6] Aldosari et al, found that surface roughness of hybrid and glass ceramic was increased when immersion in coffee.[21] Firouz et al, also found that orange juice could increase surface roughness of polished zirconia-reinforce lithium silicate ceramic.[3]

In the present study, the surface roughness of polished translucent zirconia was not significantly different when immersed in different beverages for 168 hours; which was equivalent to about 6.5 years of beverage consumption.[22] This was different from the previous study since the tested material was glass ceramic. In this study, the surface roughness was not significantly increased even when the specimens were immersed in distilled water. This phenomenon was also observed by Kukiatrakoon et al, that the surface roughness of ceramic materials were increased at low level even in deionized water.[6]

The effect of temperature of beverages was previously investigated by some studies. Tuner et al, reported increasing temperature did not affect to roughness of composite resin.[23] In contrast of Bhargava et al who reported that increasing temperature could increase surface roughness of composite resin.[24] However, the effect of temperature on translucent zirconia has not been previously investigated. The result in this study showed that even the temperature was increased, the surface roughness of polished translucent zirconia was not significantly affected. High surface hardness and chemical resistance of zirconia might contribute to this phenomenon. Thus, the surface roughness of zirconia was not altered when exposed to the different type of beverages at cold and room temperature.

Conclusions

Within the limitations of this study, it could be concluded that the surface roughness of polished translucent zirconia was not affected by cold and room temperature of daily consumed beverages (orange juice, red wine, and coffee).

Acknowledgements

This research was funded by Research Institute of Rangsit University (Funding no. 48/2564).

Declaration of Interest

The authors report no conflict of interest.

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