The Effect of Orange Juice on the Surface Roughness of Polished Translucent Zirconia

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Abstract

To observe and measure the surface roughness of polished translucent zirconia after immersion in distilled water and orange juice at different temperatures. Samples of zirconia were prepared through the process of milling with a milling machine at size 8x9x3 mm^3 and polished with Komet polishing kits. They were thoroughly cleaned within an ultrasonic bath, dry with a hot air oven, and stored within a sealed container containing silica gel for moisture control. Surfaces were measured for surface roughness (R_a in nm) using a non-contact profilometer in a jig made of silicone on all surfaces. The silicone jig was to fix the position of the zirconia samples and assist in locating the position for obtaining the value R_a (nm) for zirconia samples before and after beverage immersion. The distilled water (W) and orange juice (O) were used for immersion and the temperatures selected were orange juice at a cold temperature of 5°C and room temperature of 25°C for 168 hours (n=10). The results showed that the changes in beverage types and temperatures had no effect on the surface roughness of translucent zirconia ($p>0.05$). The types of beverages and temperature did not affect the surface roughness of polished translucent zirconia.

Keywords: *Beverage, Polished, Surface roughness, Temperature, Zirconia*

1. Introduction

Dental ceramics are increasingly being used in dentistry to fabricate both anterior and posterior restorations. This primarily is the result of their excellent esthetics properties, biocompatibility, and polishability to minimize plaque accumulation and prevent gingival inflammation. The color, texture, and translucency are close to natural teeth that are more esthetic than other restorations. Furthermore, the development of computer-aided design/computer-aided manufacturing (CAD/CAM) technology could increase the materials of choice for ceramic restorations including glass-based ceramic, and polycrystalline ceramics (Gracis et al, 2015; Bajraktarova-Valjakova et al, 2018).

Monolithic zirconia, one type of dental ceramic, has advantages over porcelain fused to metal (PFM) restorations and other ceramic restorations. The zirconia does not require as much tooth reduction as glass-based ceramic restoration. The monolithic material reduced the potential of chipping and fractures associated with the use of veneering ceramics. Furthermore, it can be milled and stained prior to sintering, which is faster and more cost-effective in processing than layered zirconia restorations. However, conventional zirconia is high opacity and is less esthetic than glass-based ceramic restorations. Recently, many manufacturers solved this problem and have launched high-translucency monolithic zirconia restorative materials which have good esthetics and excellent strength properties (Firouz et al., 2019).

Upon receiving the restoration, alteration of the finished product is a common practice due to clinical adjustments made prior to cementation. Occlusal and proximal contours alteration is a normal practice. This alteration removes glazed layers from the restoration producing surface roughness which can compromise mechanical strength and area for plaque accumulation, leading to a potential increase in periodontal disease (Malkondu, Tinastepe, Akan, Kutanoglu, & equipment, 2016). Furthermore, a rough surface will also change and affect the color and appearance of restoration by reflecting an irregular and diffuse pattern of light (Sarac, 2006).

The surface of zirconia restoration is usually exposed to changing oral environments; therefore, prevention of surface alteration is important. A study of the alteration in surface roughness of restoration explains that the surface can be degraded from food ingredients or beverages with acidic agents (low pH) (Kukiattrakoon, Hengtrakool, & Kedjarune-Leggat, 2011). For example, hydroxyl ion (OH^-) from an aqueous solution is able to infiltrate and destroy the overall molecular structure of restoration. This process is known as "Low-temperature degradation" (LTD) (Miyazaki et al, 2013; Gao, 1999). Both acidic agents and LTD result in surface roughness alteration of zirconia restoration which promotes plaque accumulation (Bollenl, Lambrechts, & Quirynen, 1997).

As time passes, zirconia undergoes degradation because of mechanical usage and exposure to multiple chemical agents. However, there is limited evidence documenting surface alteration by acidic agents combined with temperature on zirconia restoration. Thus, this study aims to evaluate surface roughness altered by acidic beverages that we consume daily and whether temperature plays a role in acid interaction with the restoration (Rashid, 2014).

2. Objective

1) To find out the surface roughness of zirconia altered by different types of beverages
2) To find out the surface roughness of zirconia altered by different temperatures of beverages

3. Materials and Methods

3.1. Specimen Preparation

Polished translucent 5Y-TZP zirconia (VITA YZ® XT White, Vita Zahnfabrik, Germany) would be used as samples with the same lot number. Un-sectioned disc size 48x54x18 mm^3 of translucent zirconia would be designed using CAD-CAM software and milled using DWX-51D 5 Axis Dental Mill, Roland DGA. Rectangular shaped samples size after condensation shrinkage which occurred after sintering was 8x9x3 mm^3. The samples were then cleaned with ultrasonic cleaner (VGT-1990, QTD, China) at 40 kHz for 5 minutes with deionized water, according to the manufacturer's instructions.

Both the CAD/CAM and milling process had been operated by the same technician. The samples were sintered with Sintra plus (Shenpaz, Israel) according to the manufacturer's guidelines. The final temperature was held at 1450°C for 120 minutes, followed by slow cooling at the rate of 25°C per minute.

The samples were then again cleaned with an ultrasonic cleaner at 40 kHz for 5 minutes with deionized water. A single operator polished the samples by using a Komet polishing flame shape 94020C with 6,000 rpm in a dry condition for 5 strokes per sample, changing the polishing flame every 5 samples. From our pilot study, polishing for 5 strokes and replacing polishing bur every 5 specimens produced similar values of R_a. The sample size in this step should be around 8x9x3 mm^3. Then, the samples were randomly allocated into 4 groups, as there were 2 types of beverages and 2 subgroups, as each beverage was stored at 2 different temperatures.

Table 1 The 4 groups of beverages at 2 different temperatures in which the zirconia samples (N = 40) would be immersed.

Group	Immersion solution	Manufacture	pH	Temperature	Duration
W5	Distilled water	NP chem	7.00	5°C	168 hours
W25				25 °C	
O5	Orange juice	Tipco	3.59	5°C	
O25				25 °C	

3.2 Beverage type selection, preparation, and storage

Two types of beverages: Tipco orange juice and distilled water were undergone an experiment with the prepared samples. The translucent zirconia samples were submerged in the beverages in Petri dishes. The size of the Petri dishes was 60 mm in diameter and 15 mm in height. The volume of 9 mL of beverages was adequate for submerging the samples with 8 mm thickness for this experimental study.

Figure 1 shows the immersion of zirconia samples in beverages.

Each type of beverage was prepared at cold temperature (5ºC) and room temperature (25ºC), in which all types of beverages were stored and incubated at the same temperature as the initial temperature for 168 hours. Beverages were refreshed every 12 hours to re-establish the condition of the beverage's pH as acid deteriorates over time. The estimated time for refreshing beverages is 5 minutes (±2 minutes). The pH meter (Thermo/ORION 2 star) will be used to confirm the pH of the refreshing beverage, the error of pH which exceeds ± 0.01 mm will not be accepted.

The specimens were cleaned by ultrasonic at 40 kHz for 5 minutes before and after immersion then dried under a hot air oven to avoid moisture contamination. After that, zirconia blocks were evaluated under a non-contact 3D profilometer.

3.3. Surface roughness measurement

A non-contact profilometer (Alicona, Austria) was used to measure the surface roughness (R_a) 2 times, before and after immersion. The data obtained were then used to compare the difference in the surface roughness before and after the immersion of the samples in the beverages.

Dental polyvinyl siloxane impression material (Provil® Novo Putty) with discord area size 5x5 mm^2 was used to selectively locate the area of the testing site for precise comparison of before and after surface evaluation under both profilometers. Each piece of 1 Dental putty was used as an index in each type of beverage. Measurement of surface roughness was done in 3 areas on the same surface of each zirconia sample: the center, lower left, and upper right (lower left and upper right position will be located 1 mm from the inner corner of the putty index). Each area size of measurement will be 0.4x0.4 mm^2.

Zirconia samples were marked at the upper right corner to identify the first surface, and the second (opposite) surface has no mark on it. The lateral surface of each zirconia sample was carved to identify the number of each sample.

For the evaluation of surface roughness by a non-contact 3D profiler, the samples needed to be placed for 10º - 15º for the least scattering of light that would influence the results of measurement. The angle of each specimen was individually recorded as a reference for placing the specimen at the same position after beverages immersion.

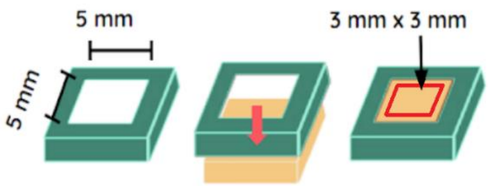

Figure 2 shows the pattern of a putty index to assist in selectively locating the area of the testing site.

3.4 Data collection and analysis

The mean difference of surface roughness in each group was analyzed with Shapilo-Wilk for normal distribution. Then Two-way ANOVA was performed at a 95% confidence level using IBM® SPSS® Statistics V25.0 (SPSS Inc., New York, USA).

4. Result

The Shapilo-Wilk showed that the data in all groups was normal distribution (p>0.05) as shown in Table 2.

Table 2 Sharpilo-Wilk test for normal distribution and mean surface roughness changing (μm) of each group.

Group	Shapiro-Wilk	ΔR_a (Mean ± SD)
W5	.483	179.368 (47.133)
W25	.092	187.067 (45.926)
O5	.566	188.101 (54.810)
O25	.748	206.966 (42.314)

Levene's test showed the variance between groups was not statistically different (p>0.05). Thus, Two-way ANOVA was performed.

Table 3 Tests of Between-Subjects Effects using two-way ANOVA statistical analysis.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4125.224[a]	3	1375.075	.060	.980
Intercept	1449714.002	1	1449714.002	63.547	<.001
Beverage	2049.536	1	2049.536	.090	.766
Temperature	1763.956	1	1763.956	.077	.783
Beverage * Temperature	311.732	1	311.732	.014	.908
Error	821280.522	36	22813.348		
Total	2275119.747	40			
Corrected Total	825405.746	39			

a. R Squared = .005 (Adjusted R Squared = -.078)

The result showed that types of beverage and temperatures did not significantly affect to surface roughness of polished translucent zirconia (p>0.05), and both factors together did not produce any significant effect (p>0.05). Thus, the first null hypothesis was accepted due to no significant difference in R_a when immersion in distilled water and orange juice with the control group being distilled water immersion. The second null hypothesis was also accepted due to no significant difference in R_a between immersion in the beverages at a cold temperature of 5°C and room temperature of 25°C.

5. Discussion

The surface of zirconia restoration is usually exposed to changing oral environments and can be degraded from food ingredients or beverages with acidic agents (low pH), resulting in a change of R_a of polished translucent zirconia material (5Y-TZP zirconia; VITA YZ® XT White). This research was carried out to simulate the change in surface roughness with various types and temperatures of beverages to determine the impacts of low pH beverages on the material's surface roughness change.

The polishing of monolithic zirconia specimens in this investigation was done using a manual polishing regimen by Komet polishing kits that were developed specifically for polishing on monolithic zirconia without water coolant. Even the monolithic zirconia may be glazed from the laboratory but when the surface was adjusted in the clinic, the surface is usually polished after occlusal and contour adjustment prior to cementation. Thus, this research was observing the polished monolithic translucent zirconia.

The change in surface roughness could be due to the surface texture being exposed to various types and temperatures of exposure solution. Orange juice is one of the most commonly consumed beverages around the world. This contains some acidic agents which can cause dental erosion, mainly citric acid, and ascorbic acid. Other acids that contribute to the nutritional profile of oranges include folic, pantothenic, hydroxycinnamic, malic, and oxalic acids. (Firouz et al., 2019) It is known that restorative materials can absorb water and other acidic fluids, causing surface degradation. Previous studies have shown that water could act as a conductor for acidic penetration (Scotti et al., 2021).

The result of this research indicated that low pH beverages had no effect on the surface roughness of translucent monolithic zirconia. Citric acid weakly degrades ceramic materials by chelating and ion leaching mechanisms. (Anusavice, 1992) The study of zirconia reinforced glass-ceramic indicated that 2% of citric acid could degrade the glazing surface of this material by increasing the R_a in 8 hours of immersion (El Sokkary, Elguindy, & El Shihi, 2018). Citric acid from the acidic beverage was shown to increase the surface roughness on feldspathic, aluminous, leucite-reinforced, and fluorapatite ceramic after 168 hours of immersion (Al-Thobity et al., 2020; Kukiattrakoon et al., 2010). Consequently, there were surface roughness changes after immersion sample surfaces in different types of beverages but no significant difference. In contrast to Xie et al, the study 20% of citric acid could not damage the translucent zirconia surface in the ambient temperature for 7 and 14 days which was the same as that observed in this study (Xie et al., 2015). As surface finishing processes of zirconia restoration could be done by glazing with glass or polishing, the glazed zirconia may be affected by acidic beverages. Therefore, further investigation should be conducted. Zirconia restoration is one of the materials that has good chemical resistance properties. An increased yttria component as a dopant may render this material to be more stable in different situations, such as acidic environments and low pH (Aldamaty et. al, 2020). Thus, the orange juice, which is considered an acidic beverage, might not affect the surface roughness when compared to the distilled water.

The two temperatures chosen for this research were 5°C, which is the temperature of iced beverages, and 25°C, for room-temperature beverages. The 5°C was recorded within an iced beverage as it is melting, absorbing heat from the surroundings, and a temperature of 25°C was recorded within an air-conditioned room. The temperature of 37ºC was not chosen because the drinks that will be in contact with zirconia will most likely be at 25ºC at a standard room temperature rather than body temperature. The drinks chosen are typically swallowed within a few seconds, not left until the temperature has adjusted to body temperature. The main reason for disregarding hot temperature was because orange juice was not typically drunk hot. The high temperature was entirely disregarded as it does not represent real-life practice. Further investigation can be conducted at higher temperatures and other beverages, such as coffee which could be served hot and cold, for exploring the other end of the spectrum to see if high temperatures could produce significant results or not despite chosen drinks not typically served hot.

Instead of using artificial saliva as our control group, distilled water was chosen to isolate our variables from other unnecessary factors such as protein or enzymes. This was done to prevent any possible intervention and contamination that might affect the pH value of the entire solution. Distilled water was preferred as its pH is neutral and purified from contaminants. The chosen duration for immersion was 168 hours to represent real-life scenario exposure to beverages for 22 years (Kukiattrakoon et al., 2010).

6. Conclusion

From the limitation of the current study, it could be concluded as follows:

1) The surface roughness of polished 5Y-TZP was not affected by orange juice.

2) The increasing temperature of orange juice from 5 to 25°C did not affect the surface roughness of 5Y-TZP.

Thus, in terms of surface roughness, changing the 5Y-TZP was not affected by orange juice at cold and room temperature when compared with distilled water.

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