

# The Influence of Oral Environment on the Optical Properties of Heat-pressed Ceramics

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*The interest in aesthetics of dental materials is becoming greater with time and dental ceramics have proven excellent aesthetic properties. The study investigated how does the oral environment and the different surface finishing affect the optical properties and roughness of two types of ceramic, obtained using the heat-pressed method. Results showed that immersion has some influence on the optical and roughness of the two types of ceramics, but the major influence is made by the surface finishing and the type of ceramic. Lithium disilicate ceramic proved to have better optical properties compared to feldspathic ceramic. Roughness values showed that the parameters (Ra and Rz) were influenced by the surface finishing for both type of ceramics.*

**Keywords:** heat-pressed ceramics, lithium disilicate ceramic, optical properties, roughness

The colour of the dental restorations has always been a major interest in the clinical dentistry. Colour is a visual effect caused by the way light is transmitted, reflected and absorbed [1]. The colour perception is influenced by the interplay between the objects, the observers and the source of the light [2,3]. For many years the clinical assessment of the tooth colour was done visually by the dentist using the shade guides that matched the colour of the tooth under the same lighting conditions. A more standardized colour assessment of the tooth can be done using special devices such as colorimeters and spectrophotometers [4-6].

Spectrophotometers measure the spectral reflectance or transmittance. Transmittance is particularly important for dental restoration and it is defined as the amount of light transmitted through the material after disregarding the reflected and absorbed light [7]. The CIELAB system is frequently used to observe colour differences. This system is composed by the following coordinates L\* (luminosity), a\* and b\*. Coordinate L\* is attributed to lightness of the material and it represents the differences between the brightness and the darkness. The coordinate a\* corresponds to differences in red- green axis and the b\* coordinate corresponds to differences in yellow- blue axis [8]. In fact, lightness is considered one of the most optical properties, because the human eye is more sensitive to this property than to chroma or hue [9].

The optical behaviour of the ceramic materials is often influenced in the mouth by the value of the pH found. The value of pH can change depending on the ingested foods and beverages. The pH range experienced in the oral cavity can vary between 1 to 10 [10] with the highly acidic conditions associated with reflux of gastric fluids [11]. The pH of ingested beverages ranges from 3 to 8 [12]. Apart from the range of pH, the oral cavity experiences a substantial temperature range from 0 to 67p C. In vitro studies have shown that the ceramic materials are susceptible to corrosion in the range of oral fluid pH [13].

Ceramic corrosion can affect the roughness of the materials, which can affect the survival rate of the prosthetic restoration [14, 15]. Ceramics can be classified by their microstructure (type of crystalline phase and glass composition), processing technique powder/liquid, pressed, or machined), and clinical application [16]. Furthermore,

polishing and glazing are also applied to finalize surface texture of the ceramic material, reduce roughness and enhance light transmission influencing the optical properties.

The aim of this paper is to investigate how does the oral environment and the different surface finishing affect the optical properties of a lithium disilicate and a feldspathic ceramic.

## Experimental part

Two commercially available hot pressed dental ceramic materials were used in the present study: a feldspathic glass ceramic and a lithium disilicate glass ceramic (table 1).

**Table 1**  
MATERIALS USED IN THIS STUDY

Ceramic system	Type	Composition
Vita PM 9 Medium Translucent	Feldspathic glass ceramic	Feldspar oxide
IPS e.max Press Medium Translucent	Lithium disilicate glass ceramic	57-80% wt% SiO <sub>2</sub> , 11-19 wt% Li <sub>2</sub> O and other oxides such as K <sub>2</sub> O, MgO, ZnO, Al <sub>2</sub> O <sub>3</sub> , P <sub>2</sub> O <sub>5</sub> .

The specimens were fabricated according to the manufacturer's guidelines. Each obtained specimen was 1.5 mm thick and had 16 mm diameter. The wax patterns were invested in a phosphate- bonded investment material [Bellavest SH; BEGO GmbH & Co. KG, Bremen, Germany]. Prefabricated ingots with medium translucency were pressed into 24 ceramic specimens using the lost- wax technique.

The pressing process was performed using a press furnace [Multimat 2 Touch+ Press Dentsply; Salzburg, Österreich] according to the manufacturer's guidelines.

24 ceramic specimens, 12 of each type of ceramic were prepared for evaluating the optical properties and roughness after applying different surface finishing (glazing and polishing) and immersing the specimen in different pH and different temperature solutions. Each ceramic disk

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has 2 surfaces resulting 48 surfaces, 24 glazed and 24 polished. First of all the samples were cleaned ultrasonically. All the surfaces were prepared using first abrasive paper [220, 320, 500, 800, 1000, 2000µm] and after polished with a diamond paste with 40 µm particles, [Zirkopol; Feguramed, Germany] for 60 seconds each surface. After this step half of the surfaces were glazed. The glaze was applied using manufacturer's instruction's. Two layers of glaze were applied to simulate fabrication processes of the restoration.

The specimens of each material [n=12] were randomly divided into three groups [n=4] according to the immersion solution: Tea [Black Tea, Vallery][pH=6,5], carbonated acidic beverages [Coca- Cola][pH=2,5], Distilled Water[D][pH=7] as the control group. The temperature were chosen to simulate the oral environment with its temperature variations.

The tea was prepared using 1g of tea for 100 g of water. The ceramic disks were immersed in a closed individual vial containing 20 mL of each solution. The vials were kept in the incubator for 24 hours at temperature of 37 p C for distilled water and 55p C for tea. The vials with the carbonated acidic beverage with acid was kept for 24 hours at a 5° C temperature.

A digital spectrophotometer (Vita Easy Shade; Vita ZahnFabrick) was calibrated before using it with its calibration apparatus before the colour was taken. Colour measurements were performed using two backgrounds, white and black, and the spectrophotometer's tip (6-mm diameter) was placed onto the center of the specimens. The specimens were measured one time and recorded in the CIE ( Commision International de l'Eclairage) Lab colour space system.

Parameters TP (translucency), OP(opalescence) and CR (contrast ratio) were calculated using the formulas. The translucency parameter [TP] was calculated by the following equation:

$$TP = [(L_B^* - L_W^*)^2 + (a_B^* - a_W^*)^2 + (b_B^* - b_W^*)^2]^{1/2},$$

where subscript B refers to the colour coordinates against a black backing and subscript W refers to those against a white backing [14].

The values from a\* and b\* coordinates recorded (VITA Easy-shade 4 Advance, Vita Zahnfabrik, Germany) from the ceramic specimens placed on a black (B) and a white (W) backgrounds were also used to estimate the opalescence parameter (OP) according to the following formula:

$$OP = [(a_B^* - a_W^*)^2 + (b_B^* - b_W^*)^2]^{1/2}$$

Values of L\* parameter were also used to calculate spectral reflectance using the following equation :

$$Y = (L^* + 16/116)^3 \times Y_n$$

Y values of the samples recorded on black (Y<sub>b</sub>) and white (Y<sub>w</sub>) backgrounds were used to calculate the contrast ratio (CR) parameter.

$$CR = Y_b/Y_w.$$

CR values range from 0 that represents a transparent material and 100 a totally opaque material.

Roughness measurements were made using a profilometer [Mitotopy SJ 201].

The values of interest were Ra and Rz, Ra meaning arithmetical mean roughness and Rz meaning the maximum roughness of the analysed surface. Five measurements were made on each side of the samples.

## Results and discussions

### TP parameter [translucency parameter]

The significant changes occur after 24 hours of immersion for the feldspathic ceramic in all of the chosen immersion solutions. For the lithium disilicate ceramic the values are constantly growing after 24 hours.

After immersing the samples in tea, after 24 hours the glazed and the polished lithium disilicate samples have the same values. The feldspathic samples have much lower values, both the glazed and polished samples. After 48 hours the values for all samples from the two lines representing the two types of ceramic tend to meet and after 72 hours the lines are more similar for all the samples. There is although a remaining difference between the lithium and the feldspathic samples. The lithium samples have higher values than the feldspathic ceramic samples (fig.1).

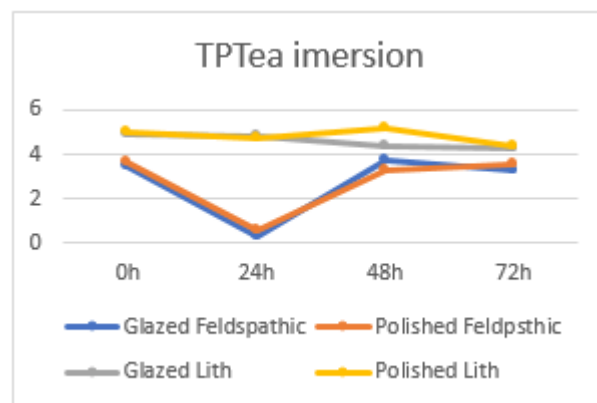


Fig. 1. TP parameter values after immersing in tea beverages

After immersing the samples in distilled water, the major differences were seen after 24 h. The feldspathic ceramic values for TP parameter decrease comparing to the lithium disilicate. After 48 h the values tend to be similar and after 72 h the values begin to increase for the lithium disilicate glazed samples (fig. 2).

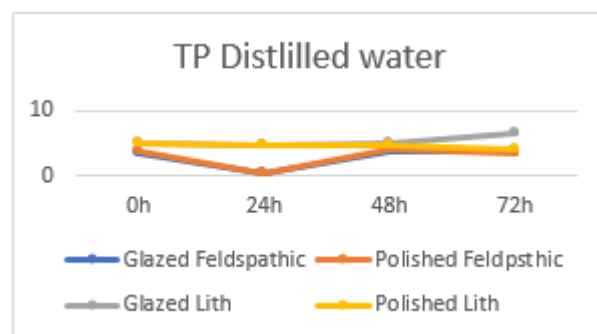


Fig. 2. TP parameter values after immersing in distilled water

After immersing the samples in carbonated acidic beverage, the values of the lithium disilicate samples begin to increase and the values for the feldspathic ceramic decrease. Even after 48 and 72 h after immersing the values are different between the two types of ceramic (fig.3).

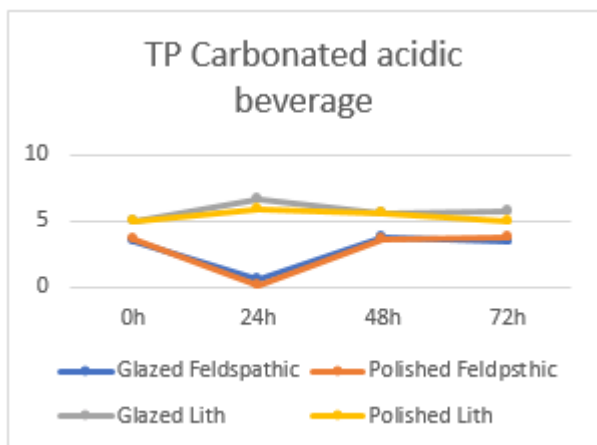


Fig. 3. TP parameter values after immersing in carbonated acidic beverages

*OP* parameter [opalescence parameter]

Similar to the TP parameter, the OP parameter changes significantly for the feldspathic ceramic, for both polished and glazed samples, after 24 h of immersion in all the solutions. For the lithium disilicate ceramic the values are constant after 24 h (fig.4).

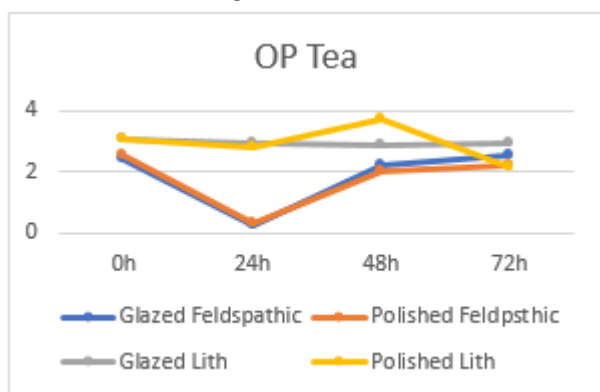


Fig. 4. OP parameter after immersing in tea

After immersing the samples in tea, for lithium disilicate samples the values were constant after 24 hours and they remain constant for the glazed lithium disilicate samples for the whole time. The polished lithium disilicate samples have values that increase after 48 h and after 72 h the values decrease. For the feldspathic ceramic, the major changes occur after 24 h and after 48 h the values are increasing again, same for 72 h. Both the glazed and the polished samples have the same path on the figure.

After 24 h of immersing the samples in distilled water, the values are high for the lithium disilicate ceramic and low for the feldspathic ceramic compared to non immersed samples. After 48 hours the values of both types of ceramic tend to be similar and are continuous even after 72 h (fig.5).

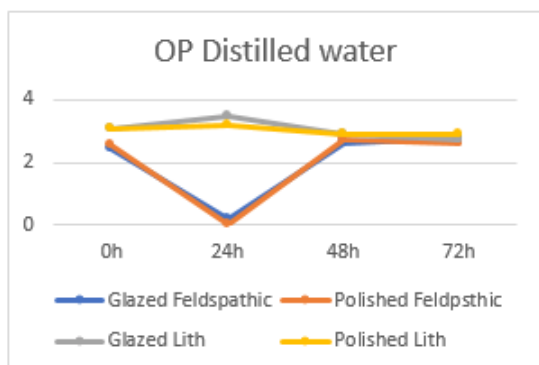


Fig. 5. OP parameter after immersing the samples in distilled water

After 24 h of immersing the samples in carbonated acidic beverage, the values of feldspathic ceramic are low compared to non immersed samples and the values for lithium disilicate seem to be constant. There is a difference between the glazed and polished after 24 h for both of the studied ceramics, the last ones have lower values for opalescence then the first ones. After 72 h the values for the glazed, polished feldspathic and polished lithium disilicate tend to decrease. The values for glazed lithium disilicate begin to increase after 72 h (fig.6).

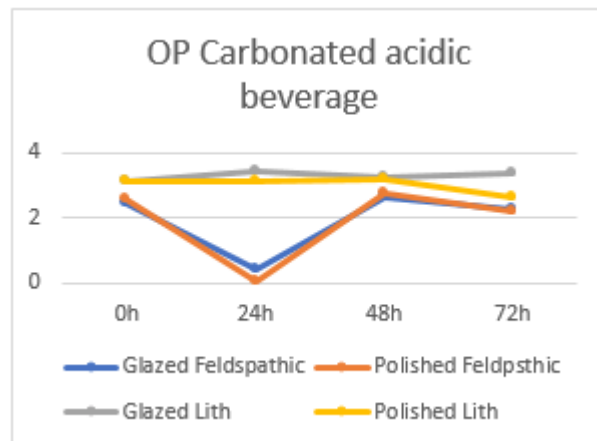


Fig. 6. OP parameter after immersing the samples in carbonated acidic beverages

*CR* parameter (contrast ratio parameters)

Differently from the other two studied parameters, the CR parameter in tea has the highest values for the feldspathic ceramic and especially for the glazed samples after 24 h. After 48 h the polished feldspathic samples have the higher values and after 72 h the glazed feldspathic begins again to have high values.

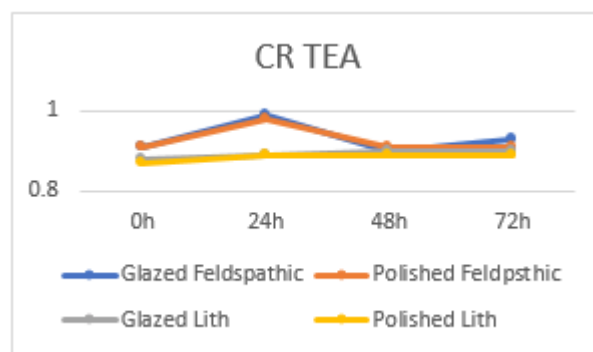


Fig. 7. The CR parameter values after immersing in tea

For the lithium disilicate ceramic, the CR parameter remains high for the glazed samples after 24 h. After 48 and 72 h the values of both glazed and polished samples continue to increase.

In distilled water, both the glazed and polished feldspathic samples have the same values in chosen time 24, 48 and 72 h. There is a difference for the lithium disilicate samples, the glazed samples prove to have a higher CR parameter after 24- 48 h and after 72 the values decrease compared to the polished lithium disilicate samples.

In carbonated acidic beverage, after 24 h the glazed and polished feldspathic samples have higher values than the lithium polished and glazed samples. After 48- 72 h the values seem to be the same and continuous.

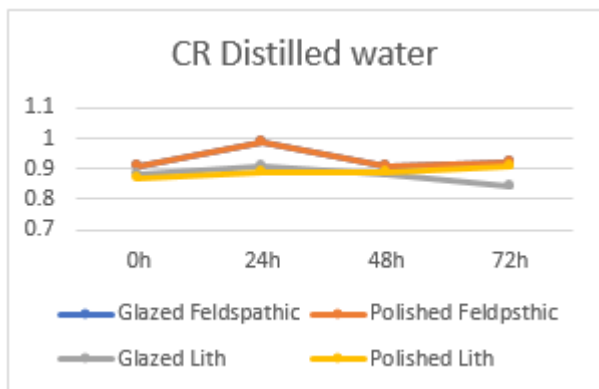


Fig. 8. CR parameter values after immersing in distilled water

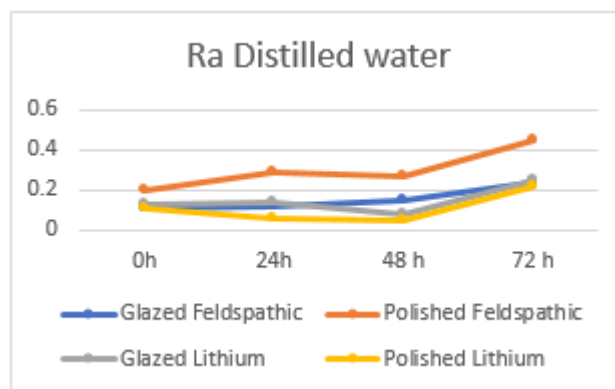


Fig. 11. Ra values for the tested samples

lowest values belong to the polished lithium ceramic for the chosen time (fig.11).

After immersing the samples in carbonated acidic beverages, the highest Ra parameter belongs to the

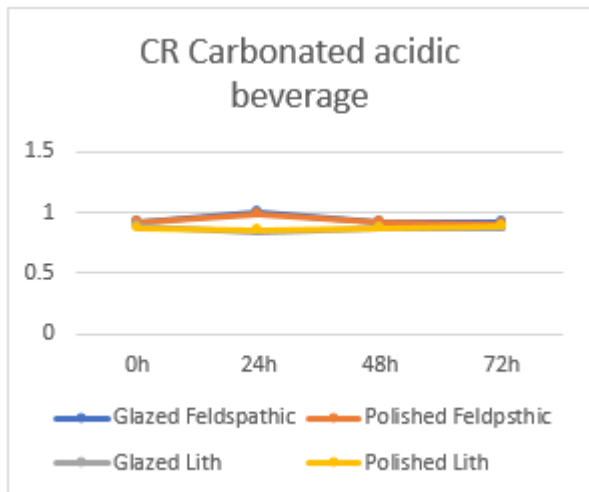


Fig. 9. CR parameter values after immersing the samples in carbonated acidic beverages

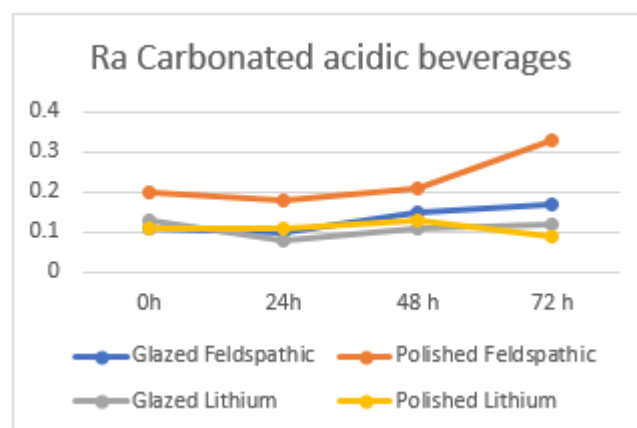


Fig. 12. Ra values for the tested samples immersed in carbonated acidic beverages

polished feldspathic ceramic. The lowest Ra values are for the lithium polished samples (fig.12).

*Rz parameter*

Rz parameter represents the highest roughness of the material. The Rz values after immersing the samples in tea proved that the polished feldspathic ceramic has the highest values after 24 and 72 h. The glazed feldspathic has lower values after 24 and 72 h but higher after 48 hours than the polished samples. The polished lithium disilicate samples have lower values than the glazed samples after

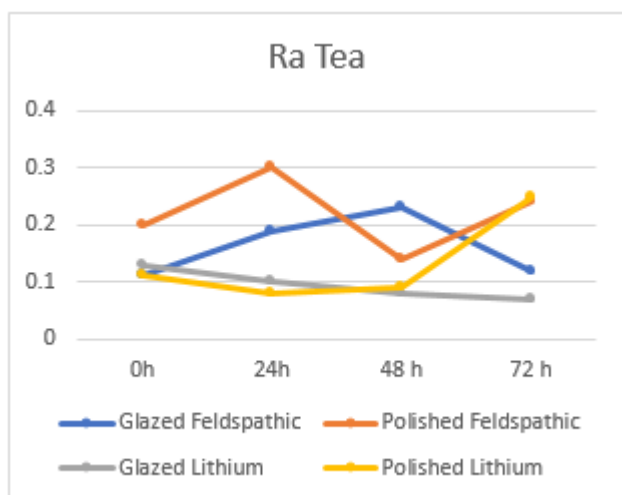


Fig. 10. Ra parameter for the tested samples

lithium are high. The lowest roughness after 24,48 and 72 h is for the glazed lithium disilicate samples (fig. 10).

The polished feldspathic ceramic samples prove to have the highest Ra values and the values maintain high for 48 and 72 hours after immersing them in distilled water. The

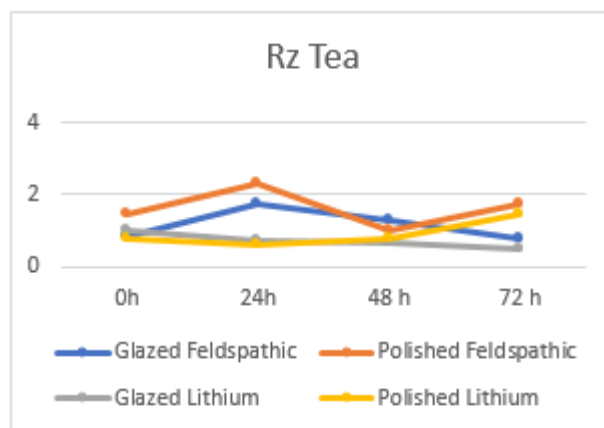


Fig. 13. Rz parameter values



24 h. After 48 h the glazed samples have lower values (fig.13).

After immersing the samples in distilled water, the differences that occur are for the glazed lithium disilicate samples. The values are higher than the polished samples

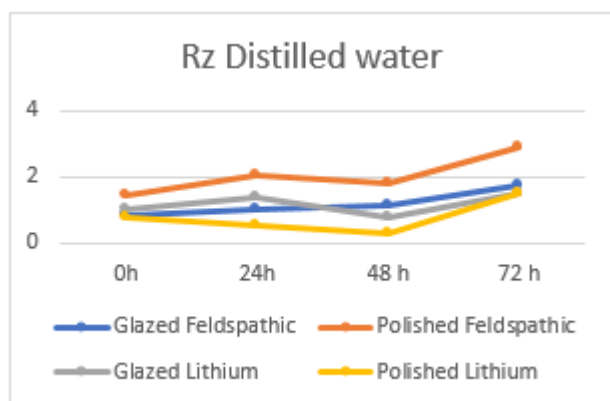


Fig. 14. Rz parameter values

after 24 h. The lower values for Rz parameter are for the polished lithium samples (fig.14).

After immersing the probes in distilled water for the chosen time the Rz values were higher for the polished feldspathic ceramic and lower for the polished lithium disilicate ceramic. The differences between the two ceramic according to the surface finishing were kept during all the time.

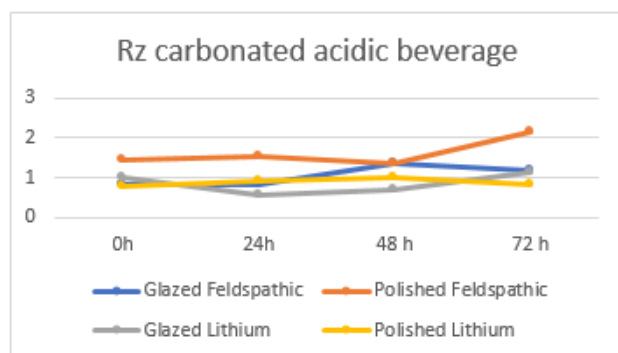


Fig. 15. Rz parameter values

In carbonated acidic beverages the polished feldspathic Rz values were high and the lower values of Rz belong to the glazed lithium disilicate ceramic (fig. 15).

The results of this study showed that the immersion has some influence on the optical and roughness of the two types of ceramics, but the major influence is made by the surface finishing and the type of ceramic. The present study simulated the clinical situation in which the lithium disilicate ceramic and feldspathic ceramic are immersed in tea, distilled water and carbonated acidic beverages for 72 hours which represents 4 years of clinical use. Ceramic materials have intrinsically multiple flaws after obtaining them because of the distribution of crystals in the glassy matrix and and sealing these flaws with polishing and glazing should improve the surface of the ceramic[15].

Some authors found that the initial smoothness of the glazed surface of ceramic to be superior to the polished surface [16,17] and some authors considered that the polished surface could equal the glazed surfaces. The results of this study concluded that it depends on the type of the ceramic. The polished surface of the lithium disilicate

ceramic was smoother than the glazed and for the feldspathic was the contrary.

The optical properties such as TP, OP and CR were influenced by the immersion in the solutions. In all solutions after 24 h there were visible changes for both ceramics, but the feldspathic ceramic proved to be more influenced. The TP and OP parameters were higher for the lithium disilicate ceramic, meaning that it has higher translucency and opalescence that are needed for aesthetic effect. The CR parameter was high for the feldspathic ceramic proving that the feldspathic ceramic is more opaque than the other one and that influences the aesthetics.

The translucency parameter [TP] is a standardized method to calculate translucency considering the entire visible spectrum [18]. For materials commonly viewed in reflection, the TP can be established as the colour difference between a specified thickness of material on black and white backings. The microstructure of the ceramic, mainly the average particle size, may explain the differences in TP values [19].

Previous studies [20,21] concluded that it is a strong correlation between that TP and CR parameters as TP decreases, CR increases. The feldspathic ceramic has an decreased TP parameter and a higher CR value. Especially the CR parameter was higher for the feldspathic probes immersed in tea and carbonated acidic beverage. CR measures diffuse reflectance, does not detect small changes in light transmission, when materials present high scattering and absorption coefficients [22].

## Conclusions

Within the limitations of this study, results suggested that the major difference when it comes to optical properties depends only on the type of ceramic.

Roughness with Ra and Rz parameter showed that the parameters were influenced by the surface finishing of both type of ceramics. The feldspathic polished ceramic proved to be more rough than the glazed feldspathic ceramic. The feldspathic ceramic has indication only for glazing. There were little differences between the polished and glazed lithium disilicate ceramic. The lithium disilicate ceramic has indication for glazing and polishing. The lithium disilicate ceramic proved to have better optical properties when the optical parameters of the ceramics were compared.

The pH and temperature changes showed little effect on the optical properties and roughness of the ceramics.

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