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Physical and mechanical characteristics of conventional dental porcelain: effects of exposure environments

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ABSTRACT

This study investigates the effects of exposure environments on the physical and mechanical properties of conventional dental porcelain. Dental ceramic disc samples of 5 mm diameter and 2 mm thick were fabricated and then subjected to soaking for four weeks in three different types of wet media namely, distilled water, soft drink (Cola) and rice vinegar. Scanning electron microscopy (SEM) analysis was performed to characterize the physical properties, while the compression test evaluated the mechanical properties. It was observed that both the acidic environments (i.e. Cola and rice vinegar) deteriorated structural integrity and thus accordingly decreased the fracture strength of the tested dental porcelain. However, Cola being relatively more acidic had greater effects in compared to rice vinegar.

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1. Introduction

Dental porcelain (a kind of bioceramic) is often used for dental restoration as the CaCo3 is used for bone regeneration [1], and PCL/PEG is used for other tissue formation [2]. Soft drinks that include Cola are considered to be the most common sources of acid among the regular individual's daily consumptions. Oncag *et al.* [3] studied the effects of acidic soft drinks on the shear bond strength of orthodontic brackets and also evaluated the physical condition of the enamel through SEM. In their study, extracted teeth were tested dividing into three groups e.g. Cola, Sprite and control group. The results showed lower shear strength for samples from Cola and Sprite groups compared to the control group, with the Cola group having the lowest shear resistance. SEM results also showed more extensive damage in Cola group compared to the Sprite group. It was concluded that soft drinks like, Cola and Sprite can have a negative effect on the bracket retention against shear forces and the patients undergoing orthodontic treatments were advised to avoid soft drinks.

Ulusoy *et al.* [4] concluded in their study which was also about the effects of herbal teas on the shear bond strength of orthodontic brackets that Cola was a causative factor in bracket-enamel bonding failure. In this study, besides using four different kinds of herbal tea, Cola and distilled water were also used as control groups. The study showed that lower the initial pH of the drink, the lower was the shear bond strength. Both Rosehip fruit tea and Cola which had acidic pH values resulted in lower shear bond strength values. The researchers also recommended that any adult patients receiving fixed orthodontic treatments should beware of the potential damage that could be caused by Cola, rosehip fruit tea or any other soft drinks with low pH values. Squivel-Upshaw *et al.* [5] not only considered acids but also other values along the pH scale for their case study in determining the effects of environmental pH on the surface degradation of dental ceramics. The SEM results for the specimens tested in the environments with pH 1 and pH 2 were similar, as both types of samples showed pitting in certain areas suggesting ionic exchange took place. However, the test using pH 1 showed greater pitting on the surface area.

2. Materials and methods

2.1. Preparation of samples

For this study, IPS In-Line Dentin A1/TI1 (Ivoclar Vivadent-Germany), porcelain powder was used. To prepare the slurry, some porcelain powder was mixed with distilled water and also some Ceram Build-up liquid. The slurry was then casted into a metallic mould with diameter of 5.5 mm and thickness of 2.5 mm, using a brush. A larger dimension mould was used to compensate for the shrinkage that would occur during the sintering process. The mould

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was filled in excess with slurry and excess water was applied on the surface to ensure even filling. A paper towel was used to absorb the excess water and to compact the slurry in the mould [6,7]. The condensed sample was then removed from the mould and placed in an oven for sintering (Programat P300 IvoclarVivadent). The initial temperature and firing temperature of the oven were set at 450 °C and 910 °C, respectively. The heating rate was set at 60 °C/min. The whole firing process took approximately 15 minutes. Therefore, the samples were sintered by batches of 12–15 each time. The cycle was repeated until the whole 65 samples were completed.

These primarily fired samples were then sent for glazing. Ducera All-Ceram glaze was used in this study. The glaze powder was simply mixed with distilled water to form slurry, which was then applied onto the surface of the samples evenly using a brush. The glazed samples were placed into another oven for final firing (Programat P500 Ivocalar Vivadent). The firing process for glazing took approximately 23 minutes with initial temperature of 575 °C and firing temperature of 1050 °C, at a heating rate of 55 °C/min.

2.2. Soaking the samples into solutions

Out of the 65 samples, five samples were used as dry control samples for testing. The remaining 60 samples were divided equally into three groups namely, distilled water, Cola and rice vinegar groups, that is, 20 samples for each group. Five samples were put into each petri dish and thus four petri dishes were prepared for each solution. The petri dishes were then labeled appropriately according to the soaking periods, that is, one week, two weeks, three weeks and four weeks. The samples were kept in storage at room temperature and were removed routinely on weekly basis, and dried properly before characterization.

2.3. SEM analysis

A representative sample from each petri dish was analyzed using a field-emission scanning electron microscope (FEI/Quanta400F), operated at 10 kV under low vacuum settings to investigate the surface morphology of the specimens.

2.4. Compression test

All specimens were subjected to compression using a universal testing machine (INSTRON 3365) with load capacity of 5 kN. Maximum load at failure was measured for all specimens and divided with surface area of the specimen to obtain the fracture strength. The load was applied through a circular flat punch with diameter of 48 mm at a crosshead speed of 1 mm/min. Five samples were tested for each time point for each group of sample and the average value of the fracture strength was calculated. For the fracture strength measured, a Student's t-test was performed in comparing results from two independent sample groups. In all the statistical tests performed, a significance level of 0.05 was used.

3. Results and discussion

3.1. Physical characteristics

The samples soaked in distilled water showed no significant change in surface morphology throughout the soaking period. Only some minor pits were noticed (Fig. 1) perhaps due to uneven filling of the mould during fabrication process. Unlikely, SEM images of the samples soaked in Cola and rice vinegar showed rougher morphology with gradual increase in surface roughness from week one to week four (Figs. 2 and 3). Generally, the samples soaked in both Cola and rice vinegar underwent hydrolysis of the porcelain that led to the erosion of sample surface. Overall, the longer exposure of the samples to the acidic environment increased the extent of surface roughness in both types of samples. However, the morphology of the samples soaked in Cola changed more than that soaked in rice vinegar.

Both Cola and rice vinegar have acidic pH values (Cola 2.44 and rice vinegar 2.6–3.2). However, as per pH values Cola appears to be more acidic than rice vinegar. Overall, this acidic pH value makes these solutions highly erosive to the porcelain and thus longer exposure of the samples to these solutions caused demineralization. Price *et al.* [8] commended that the demineralization could occur in ceramic material when the pH value would drop below 5.2. This current study aimed to investigate the effects of acidic solutions which are commonly consumed in our daily lives on dental ceramics. Distilled water was chosen as a control group to simulate wet oral conditions produced by saliva in a human mouth, as used in some other studies [4,9]. Cola was chosen because, many children as well as young adults nowadays consume it regularly, and also because it had been proven to have a negative effect on enamel [10]. Besides, rice vinegar was chosen as a second acid solution to determine the effect of another acidic solution which is also commonly used in cooking.

The SEM images showed that hydrolysis and thus demineralization of the samples soaked in Cola and rice vinegar resulted in a rougher surface. Hydrolysis can be defined as the loosening of bonds due to attack of water. In this case, soaking the samples in acidic media might result in the splitting of the silicon-oxygen bond in the ceramic material because of the hydroxyl group (OH^-) from the acid [11]. Hydrolysis can result in crack propagation which explains the drop in fracture strength of the samples soaked in both Cola and rice vinegar. The SEM analyses revealed that the

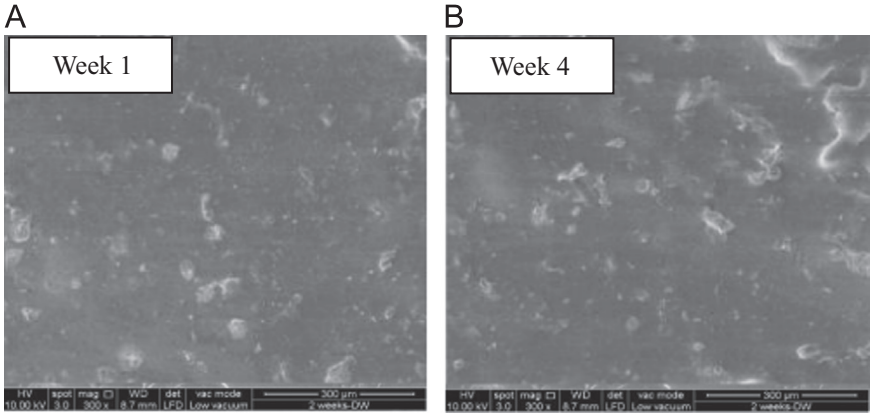

Fig. 1. SEM images of the samples soaked in distilled water for different time periods; A: 1 Week & B: 4 Weeks.

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