EGYPTIAN DENTAL JOURNAL
www.eda-egypt.org
Vol. 68, 1767:1773, April, 2022
Print ISSN 0070-9484 • Online ISSN 2090-2360
Fixed Prosthodontics and Dental Materials
Submit Date : 2022-03-06 • Accept Date : 2022-03-17 • Available online: 2022-03-30 • DOI : 10.21608/edj.2022.125679.2009

# IMPACT OF SIMULATED GASTRIC ACID ON COLOR STABILITY OF DIFFERENT TYPES OF DENTAL CERAMICS

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### *ABSTRACT*

**Purpose:** The purpose of this in vitro study was to evaluate the impact of simulated gastric acidity on color stability of different types of dental ceramics.

**Materials and Methods:** Fifty specimens were constructed according to type of the material into five groups (n=10), as follows: Partially stabilized zirconia (PSZ) **(Prettaue),** Fully stabilized zirconia (FSZ) **(Prettaue Anterior),** lithium disilicate ceramics (**IPS**. **Emax**), **Zirconia**-containing lithium silicate ceramics (ZLS) **(Vita Suprinity)** and Hybrid ceramics (**Vita Enamic**). All specimens were cut with a low-speed diamond saw (Isomet) into a rectangular shape with the following dimension: 12mm width x 14mm length x 1 mm thickness. Color stability was evaluated by reflective spectrophotometer. Each specimen was immersed in 5 ml of the simulated acid of ph 1.2 for 96 h in a 37˚C incubator. One-way ANOVA was used to compare mean difference between groups.

**Results:** There was highly significant difference (P=**0.000**) between all groups. Prettaue group showed the least amount of color change (2.97±1.27), while vita enamic group showed the highest color change (5.97±3.29).

**Conclusions:** The gastric acid changed the color of all types of dental ceramics. Except for Partially stabilized zirconia and lithium disilicate ceramics, the color change of all other ceramics was noticeable to the human eye and then was clinically unacceptable..

**KEYWORDS**: ceramic restoration, optical properties, gastric reflux, dental ceramics, color stability.

## INTRODUCTION

Dental erosion is defined as permanent loss of dental hard tissue by acids not caused by bacterial action. These acids may be from either external (e.g. dietary) or intestinal (e.g. gastric) sources.[1] Loss of the tooth surface can be due to four main reasons: erosion, abrasion, attrition and abfraction.[2,3] Many factors contribute to the existence of gastric acid inside the oral cavity, including bulimia nervosa, gastroesophageal reflux disease (GERD), eating disorders, repeated vomiting and rumination.[4, 5]

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Gastroesophageal reflux disease ( GERD) is a long-term disorder in which uncontrolled muscle relaxation enables contents of stomach to travel upward through the oesophagus to the oral cavity.[6]

Bulimia nervosa is characterized as a condition related to excessive weight and shape concern, binge eating, excessive self-purging, and other unhealthy activities to avoid weight gain.[7, 8]

For both GERD and bulimia, gastric acids cause demineralization of the tooth surface and degradation of dental tissues, leading to loss of enamel and dentin. Extended exposure to acid results in the loss of tooth brilliance, presence of shallow concavities coronal to the cement-enamel junction (CEJ).[9] Clinical manifestations of this form of dental erosion could be apparent only after frequent contact with acids several times per week for a minimum period one to two years.[10]

Restoring the damaged tooth structure can be achieved with direct or indirect restoration. With growing demands for aesthetic restorations, the possibility of manufacturing complete contour crowns and the predicted enhancement of bonding capabilities, dental ceramics have gained attention as an effective material for the restoration of eroded teeth.

Complex erosive lesions often need restorative treatment. Restorative treatment based on the complexity and extensiveness of the erosive lesions, ranging from simple procedures such as direct conservative restoration to indirect fixed or even full-bodied reconstruction.[11] Gastric acid could also affect dental ceramic restoration made to restore worn dentition.

Oral cavity restorations are susceptible to a set of variables that makes them more susceptible to color changes, which is including temperature, diet, humidity and smoking habits.[12] In the oral cavity, restorations are often exposed to a wide variety of other fluids, temperature changes, load tension, and tooth brushing. The quality of any restoration depends both on its physical and mechanical properties, and on the aesthetic appearance.[13]

Numerous studies have studied the physical and mechanical properties of dental ceramics. To date, however, inadequate researches have examined the effect of gastric acid on the optical characteristics of these products. The purpose of this study was to determine the influence of gastric juice on the color stability of these five different types of dental ceramics commonly used in dentistry. The null hypothesis to be claimed in the present study was color change of dental ceramics caused by gastric acidity is perceivable to human eye».

## MATERIALS AND METHODS

### Preparation of the specimens

Fifty Specimens were cut from CAD/CAM blocks or blanks of five different ceramic materials. The minimum number of sample size for this study is 35. The sample is collected based on previous study.[12] The significance level was 0.05 and the power sample size was more than 80% for this study and the confidence interval 95% and the actual power is 95.62%. The sample size calculated using a computer program G power version 3.

The formula of sample size

$$\text{sample size} = \frac{Z^2 P\,(1\text{-}P)}{C^2}$$

Where:

Z = Z value (1.96 for 95% confidence level)
p = percentage picking a choice, expressed as decimal
c = confidence interval, expressed as decimal.

An over sizing of the sample will be done to compensate the potential failure and increase the validity of the results, so the sample size will be 50.

The specimens had been cut using a low-speed diamond saw (Isomet, Buehler, Lake Bluff, IL, USA). The specimens were divided according to the type of ceramic material into five groups (n=10) as shown in (Table 1).

The specimens were rectangular in shape and their dimensions were 14mm length, 12 mm width and 1mm thickness. Wet SiC paper was used to grind the specimens sequentially (600, 1,000 and 1,500 grits). Polishing and grinding were done on one side of the specimens that were adjusted and polished to imitate clinical intraoral protocols. The final sizes of the specimens were also checked with a digital caliper for standardization. The specimens were washed thoroughly using distilled water for 10 minutes for cleaning, and then compressed air was used to dry them. Firing conditions of the tested groups, except for vita Enamic, were done according to manufacturer recommendations.

## Preparation of Gastric Acid

A specific gastric acid simulation formula has been used. Simulated acid was prepared by using Hunt and McIntyre approach to induce erosive enamel lesions similar to those seen in clinical practice.[14] Hydrochloric acid (HCl) 0.06 M (0.113% solution in deionized water, pH 1.2) was prepared. The pH was tracked every 24 hours and every specimen was submerged in 5 ml of synthetic gastric acid for 96 hours in a 37C incubator.[15]

## Measurement of color stability

The specimens' colors were measured with a reflective spectrophotometer (X-Rite, model RM200QC, Neu-Isenburg, Germany). The size of the aperture was adjusted to 4 mm and the samples were precisely aligned with the device. The white background was chosen and measurements were performed by using the CIE L*a*b* color space equivalent to the CIE standard illuminant D65. Each specimen was measured three times before and after exposure to synthetic gastric acid. Before exposure

TABLE (1): Specimens grouping and detailed description of materials tested in the research.

| Group | Material | Manufacturer | Product | Chemical composition |
|---|---|---|---|---|
| Group prettaue: | **Partially stabilized Zirconia** | Zirkonzahn, Taufers, Italy | Prettau | 4%–6% Y2O3, <1% Al2O3, max. 0.02% SiO2, max. 0.01% Fe2O3, max. 0.04% Na2O |
| Group prettaue anterior: | **Fully stabilized zirconia (FSZ)** | Zirkonzahn, Taufers, Italy | Prettau anterior | <12% Y2`O3, <1% Al2O3, max. 0.02% SiO2, max. 0.01% Fe2O3, max. 0.04% Na2O |
| Group IPS emax: | **lithium disilicate ceramics** | Ivoclar Vivadent AG, Schaan, Liechtenstein | IPS emax CAD ceramic | > 57 % SiO2/ Li2O/ K2O/ P2O5/ ZrO2/ ZnO/ Al2O3/MgO and Pigments |
| Group vita suprinity : | **Zirconia-containing litium silicate ceramics (ZLS)** | Vita Zahnfabrik, Bad Säckingen, Germany | Vita suprinity | 56 – 64 % SiO2-15 – 21% Li2O, 8 – 12 % ZrO2, 1 – 4 % K2O, 3-8 % P2O 1 – 4% Al2O3 and pigments(0-6%) |
| Group vita Enamic : | **hybrid ceramics** | Vita Zahnfabrik, Bad Säckingen, Germany | Vita Enamic | **Ceramic part**: 86% wt. SiO2 (58 – 63%), Al2O3 (20 – 23%), Na2O (9-11%), K2O (4-6%), B2O3 (0.5-2%), ZrO2 (<1%), KaO (<1%). **Polymer part**: 14 % wt (UDMA, TEGDMA |

to gastric juice, the mean value for every set of three measurements was labelled CIE L1*a1*b1 *; after exposure, the mean value was labelled CIE L2*a2*b2 *. Color changes (ΔE) of the samples pre and post acid immersion were analyzed by using the given formula:

$\Delta L^*=L2^*-L1^* \quad \Delta a^*=a2^*-a1^* \quad \Delta b^*=b2^*-b1^*$

$\Delta E_{CIELAB} = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})$ ½

Where: L* = lightness (0-100), a* = (change the color of the axis red/green) and b* = (color variation axis yellow/blue ).[16]

### Statistical Analysis

Mean values for each group were determined and differences between groups were evaluated for statistical significance with a one-way analysis of variance (ANOVA).

## RESULTS

Mean values and standard deviation (SD) of *L*a*b** values of dental ceramics groups were summarized in (Table 2) while mean values of *ΔE* values of for all tested groups were graphically presented in (Fig. 1).

Statistical Package for Social Sciences (SPSS version 25) was used to statistically analyze data. Statistical analysis with one way ANOVA showed a highly significant difference (P=0.000<0.005) between all groups. Prettaue group showed the least amount of color change (2.97 ±1.27), while vita enamic group showed the highest color change (5.97 ±3.29).

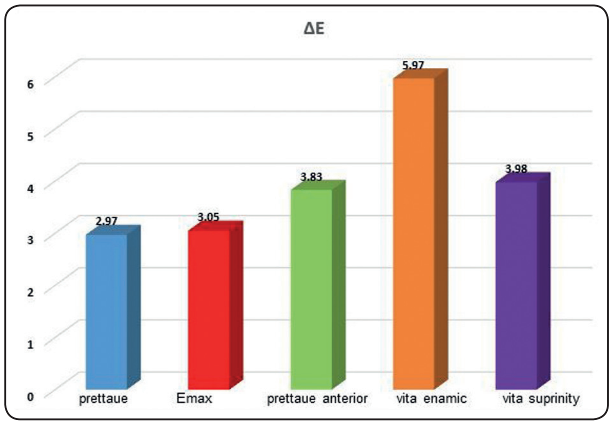


Fig. (1) Column chart showing mean color difference (ΔE) between all groups.

TABLE (2) Means and standard deviations (SD) of L*a*b* values of dental ceramics groups as measured with a reflective spectrophotometer:

| Before | Prettaue | Prettaue Anterior | IPS. Emax | Vita Suprnity | Vita Enamic |
|---|---|---|---|---|---|
| L* | 90.43±1.05 | 85.82±0.96 | 79.90±1.13 | 85.03±1.49 | 79.99±1.03 |
| a* | -1.71±0.73 | -1.66±1.02 | 1.47±0.91 | 1.24±0.56 | 1.42±0.79 |
| b* | 4.43±2.37 | -1.62±2.74 | 23.44±3.17 | 24.83±3.21 | 20.57±3.31 |
| **After** | | | | | |
| L* | 89.33±0.89 | 85.36±1.27 | 79.67±0.66 | 84.21±0.79 | 81.72±2.05 |
| a* | -0.96±0.51 | -0.86±0.99 | 1.74±0.37 | 0.83±0.68 | 1.68±0.59 |
| b* | 4.47±0.48 | -1.16±1.96 | 22.65±0.74 | 22.83±1.39 | 23.11±4.49 |
| **Difference** | | | | | |
| ΔL* | -1.10±1.57 | -0.46±1.88 | -0.24±1.09 | -0.82±1.56 | 1.73±2.43 |
| Δa* | 0.76±0.88 | 0.71±1.38 | 0.28±0.84 | -0.41±0.79 | 0.25±1.20 |
| Δb* | 0.04±2.38 | 0.46±3.35 | -0.79±3.33 | -1.99±3.80 | 2.54±5.54 |

## DISCUSSION

Limited researches have been conducted to study the effect of simulated gastric acid on the currently available ceramic restorative materials. The results of the current study rejected the null hypothesis for partially stabilized zirconia and lithium disilicate materials. On the other hand, the results accepted the null hypothesis for fully stabilized zirconia, zirconium reinforced lithium silicate ceramics and hybrid ceramics

Regarding the choice of dental ceramics to be tested in this study, five different types were selected as they are becoming increasingly popular for use due to their excellent aesthetic properties, their biocompatibility and wear resistance.[17,18] The sample thickness of 1.0 mm was chosen on the basis of the recommended occlusal thickness of the monolithic zirconia restorations.[19]

In regards to the concentration of corrosive acid and the time of immersion, there is no certain agreement among scholars on the actual gastric acid simulation and the equivalent time for replicating the in vivo model. The ISO testing standard for testing the degradability of ceramics proposes the use of 4% acetic acid for 161 hours at 80°C, which corresponds to an in vivo period of 2 years, based on the research of De Rijk et al[20]. The in vitro model of the corrosiveness of acids on the surface of dental ceramics depends primarily on the concentration of acid, the duration of submersion and the temperature.

In the present study, a stronger acid (HCl, pH 1.2) was used. Based on Hunt and McIntyre's method [14], HCL is stronger acid rather than the ISO standard of 4% acetic acid . In addition, the duration of immersion was increased to 96 hours at 37◦C which is supposed to resemble around 10 years of clinical exposure[15,21].

Color change ($\Delta$E) was classified into three significant ranges as described in the following: $\Delta E<1$ (undetectable color change), $1<\Delta E<3.3$ (acceptable color change), and $\Delta E>3.3$ (unacceptable color change).[22]

The results of the present study showed that there was color change for all materials tested. All dental ceramics, with the exception of prettaue and IPS. emax, demonstrated color variations considerably above the value of 3.3, a threshold value presumed as clinically visible to the human eye and therefore not acceptable in clinical practice.[23]

The color change was acceptable color change for partially stabilized zirconia ($\Delta E$ =**2.97 ±1.27<** 3.3). These finding were similar to other studies that indicates that zirconia is the most resistant material against acid attack.[24] This may be due to their polycrystalline microstructure that provides strength and fracture resistance. Additionally, the absence of a glass phase makes the polycrystalline ceramics more resistant to acid attack.[25,15]

The color change was also acceptable for lithium disilicate ceramics ($\Delta E$ =**3.05 ±2.04** < 3.3). these findings were similar to other studies that showed that lithium disilicate ceramics have low discoloration rate.[26,27] This may be due to high gloss and stain resistance of lithium disilicate ceramics due to their structure and the ability of their constituent atoms to slow the progress of light.[12]

In fully stabilized zirconia (prettaue anterior group), there was significant change in color ($\Delta E$ =**3.83 ±1.72>** 3.3). This may be attributable to an increase in the susceptibility of FSZ to corrosive acids with a greater amount of bead-like compounds scattered on the corroded surface of PRTA (FSZ).[15] Increased surface roughness may affect color perception and light reflection owing to surface topography changes.[23]

In zirconium reinforced lithium silicate (Vita Suprinity group), there was significant change in color ($\Delta E$ =**3.98 ±2.48>** 3.3). Unlike this study, Cruz et al found that simulated gastric acid led to a color change that was classified as undetectable.[27]

This difference may be attributed to that the exposure time was relatively shorter than in the present study.

Also, there was unacceptable color change in color with hybrid ceramics (*ΔE* =**5.97 ±3.29>** 3.3). This can contribute to polymer-containing materials having more stain than pure ceramic materials. Polymers absorb water and may also be more capable of absorbing the pigments dispersed in the staining solution.[28] This may be also attributed to the fact that the weaker polymer matrix is feasibly segregated from the ceramic network and the ability of acidic media to soften resin-based restorative materials which affect surface roughness and change color perception.[29] Previous researches have also shown that polymer containing composites exhibit clinically perceivable color change in variable staining solutions.[30,31] On the other hand, another study have shown that simulated gastric acid led to a color change that was classified as undetectable.[26]

The main limitation of this study is that there are differences between the clinical environment & the in vitro environment such as the amount of saliva and the nature of it varying from person to person and the frequency of tooth brushing. All these variables can affect the outcome data.

Despite these limitations, the results of the present study still add more information to the literature by comparing different categories of ceramic materials. Therefore, the results of the current study conclude that the material type is a crucial factor in determining whether the color change caused by gastric acidity will be perceivable to human eye and clinically un acceptable or not.

## CONCLUSION

The following conclusions can be drawn based on these findings and within the scope of this study's limitations:

1. The gastric acid changed the color of all types of dental ceramics.
2. Except for Partially stabilized zirconia and lithium disilicate ceramics, all other ceramics showed color change that was noticeable to the human eye and clinically undesirable.

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